National Climate Program

Five-Year Plan

September 1980

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Prepared in the
National Climate Program Office
National Oceanic and Atmospheric Administration

PARTICIPATING AGENCIES:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of State
Department of Transportation
Department of the Treasury
Agency for International Development
Council on Environmental Quality
Environmental Protection Agency
Federal Emergency Management Agency
National Aeronautics and Space Administration
National Science Foundation

Foreword

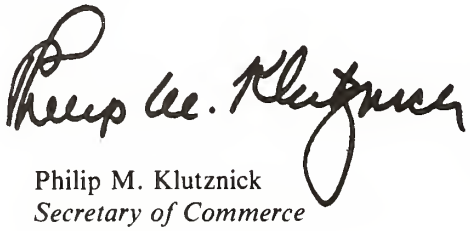
Climate affects many aspects of our lives from the production of food to our energy usage. Climate's natural variations cause hardship around the world, and there is increasing evidence that human activities might induce global climate changes.

Pursuant to the National Climate Program Act, our national efforts concerning climate have been focused into a clearly defined, well coordinated program. This Plan, required under the Act, is a clear statement of our Nation's priorities and the director of our future efforts. The strategy that has been adopted is to emphasize the early production of useful data based on our current knowledge of climate, as well as the expansion of our understanding of climate and its relationship to society.

Because the United States has taken the leadership in multinational projects like the Global Atmospheric Research Program and the International Decade of Ocean Exploration, and has continued to provide world leadership through programs like the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory and the Program of Global Monitoring for Climate Change, the National Climate Program is being established on a very strong foundation.

The Federal budget for programs concerning climate in Fiscal Year 1981 will be two and a half times the amount it was in 1977. This increase reflects the recognition of climate's significance and importance to society.

The development of this first multiyear plan for such a complex multiagency effort has been a significant undertaking that could not have been accomplished without the involvement and support of many individuals and groups. The comments and suggestions received on earlier drafts of the Plan from the Congress, and the efforts of the National Academy of Sciences Climate Research Board have been especially instrumental in guiding the development of this Plan. Finally, the extensive participation and cooperation received from the many Federal agencies involved have enabled us to prepare such a comprehensive and significant Plan.



Philip M. Klutznick
Secretary of Commerce
July 1980

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EXECUTIVE SUMMARY

Climate is the way we characterize the weather that occurs at a particular place over periods of weeks, years, centuries, or millenia. The modern notion of climate includes its variations and extremes as well as its average conditions. It also includes the state of the oceans and aspects of the Earth, like the moisture in and on its surface, that influence and vary along with climate. Climate is a major influence on the quality and character of human life. Our environment and institutions are highly sensitive to climatic fluctuations.

Extreme climatic events in recent years have emphasized the central role of climate in human affairs. A series of droughts, freezes, and other climatic anomalies in many parts of the world in 1972 caused widespread crop failures. Large purchases of North American grain by the Soviet Union and other nations had serious economic repercussions. Severe winter weather in the eastern and midwestern United States in early 1977 caused many schools, industrial plants, and businesses to close, because not enough fuel was available for heating. The "Winter of '77" also brought frost damage to the Florida citrus crop and serious water shortages to drought-stricken regions of the western United States.

At about this same time, a growing number of atmospheric scientists began to express concern that increasing concentrations of atmospheric carbon dioxide produced by combustion of coal, oil, and other fossil fuels could change the Earth's climate in significant ways.

Faced with increasing evidence of the critical and widespread impacts of climate on national concerns, the Nation's leaders concluded that a concerted effort to learn more about climate and its effects was clearly in the national interest.

The National Climate Program Act

In 1978, the Congress enacted the National Climate Program Act, Public Law 95-367. The purpose of the Act, as set forth in Section 3, is "to establish a national climate program that will assist the Nation and the world to understand and respond to natural and man-induced climate processes and their implications."

The primary mechanism to achieve this purpose is the National Climate Program, established by Section 5 of the Act. The Program, which includes both research and applications, is intended to improve our understanding of climate processes and to make useful climate information available to the Federal and State governments, industry, and the public. The objectives of the Program will be achieved through coordination of efforts among many agencies and institutions that conduct climate research and disseminate and use climate information.

This document presents a three-part plan for the next 5 years of the National Climate Program.

Part One, "Development of the Climate Plan" (Chapters I and II), introduces the National Climate Program Act and the 5-year plan and reviews existing Federal activities related to climate. It also discusses the priority-setting process for projects and activities that are proposed in response to statutory mandates as well as advice and recommendations from the scientific community.

Part Two, "The Climate Plan" (Chapters III-VI), presents specific projects and activities that are proposed in three categories that will be given special emphasis over the next 5 years:

- Providing climate products.
- Responding to impacts and policy implications of climate.
- Understanding climate.

Part Two also includes a discussion of the total scope and structure of the National Climate Program, which includes a broad base of continuing activities. These activities are organized into three components: climate impact assessment; climate system research; and data, information, and services.

Part Three, "Implementation of the National Climate Plan" (Chapters VII-IX), considers three special aspects of the program: international activities, an intergovernmental climate program that will provide cooperative Federal/State efforts, and experimental climate forecast centers to develop and test innovative approaches to long-range prediction. Part Three also discusses administration of the program and resources and future plans.

Federal Climate Activities

Existing Federal climate programs have a strength and breadth that provide a solid foundation for the National Climate Program. Seven Federal departments and agencies have substantial climate-related activities—the Departments of Agriculture, Commerce, Defense, Energy, and the Interior, the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). The Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration

(NOAA) of the Department of Commerce (DOC), NASA, and NSF account for over three-fourths of the Federal funding for National Climate Program activities. The FY 1980 budget for the climate activities detailed in the Program is $115 million, and the President's budget request for FY 1981 is $127 million.

The Program is administered by the National Climate Program Office with the assistance and guidance of several interagency bodies plus the statutory Climate Program Advisory Committee. The Office works closely with the concerned agencies, the Office of Science and Technology Policy, and the Office of Management and Budget in preparing and analyzing the budget proposals to implement the Program described in the Plan.

Establishing Priorities

Public Law 95-367 mandates that a 5-year Plan be produced to "establish the goals and priorities for the Program" and define agencies' roles, funding requirements, and expected Program achievements. The Plan serves as a guide: (1) for Federal agencies, as they develop and manage their climate programs; (2) for the research community, as the context for their studies; (3) for the private sector meteorologists and climatologists, as the source of information on Government activities that affect the availability of climate data and information products; (4) for the Congress, as it exercises its oversight, authorizing and appropriating functions; and (5) for State and local governments, as they plan and implement their activities within the framework of the National Program.

The Plan emphasizes early production of useful data and information based on our existing knowledge of climate, while simultaneously expanding our understanding of climate and its impacts on society.

Within each of the major categories of activities in the Program, two levels of priority activities are identified and described. The highest priorities are termed the Principal Thrusts of the Program. Each is a multidisciplinary, multiagency effort with a designated lead agency. The Principal Thrusts of the Program may change with time, as priorities shift or new areas of urgency and opportunity emerge. Activities at the second level of priority are termed Areas of Program Concern. These activities warrant additional efforts and focused attention during this planning cycle. These, too, are multidisciplinary, multiagency efforts. Coordination of activities is the responsibility of the National Climate Program Office.

Options for future program development are suggested in connection with many of the Principal Thrusts and Areas of Program Concern. They describe activities that are not in present agency plans that could be undertaken over the next few years. They are presented for consideration by the appropriate agencies, but the identification of an option is not a request for new resources.

The Plan's six Principal Thrusts and the designated lead agencies are as follows:

Activity Category	Principal Thrust	Lead Agency
I. Providing Climate Products	Generation and Dissemination of Climate Information	NOAA
	Climate Prediction	NOAA
II. Responding to Impacts and Policy Implications of Climate	Carbon Dioxide, Environment, and Society	DOE
	Climate and World Food Production	USDA
III. Understanding Climate	Solar and Earth Radiation	NASA
	Ocean Heat Transport and Storage	NSF

The 13 Areas of Program Concern are as follows:

Activity Category	Area of Program Concern	Participating Agencies
I. Providing Climate Products	Global Precipitation Measurements	NOAA/ NASA/DOD
	Surface Climate Data Networks	NOAA/ FAA/DOD
II. Responding to Impacts and Policy Implications of Climate	Climate-Related Hazards	DOI/FEMA/ USDA/ NOAA/ DOD/NSF
	Energy Production, Distribution, and Demand	DOE/ NOAA
	Impact Assessment Methodologies	DOE/USDA/ NOAA/ NSF/EPA
	Regional Climate Effects of Humans	DOE/EPA/ USDA/ NOAA/NSF
	Semiarid and Arid Lands	DOI/USDA
	Water Resources Management and Planning	DOI/USDA/ DOD/EPA/ DOC
III. Understanding Climate	Air-Sea Interaction	NOAA/ DOD/NSF/ NASA
	Climate Model Development and Validation	NSF/NOAA/ NASA
	Past Climates	NSF/DOI/ DOE
	Polar Ice and Snow	NSF/NOAA/ DOD/ NASA/DOT
	Stratospheric Processes	EPA/NOAA/ NASA/NSF/ DOT

Providing Climate Products

The Principal Thrusts are:

Generation and dissemination of climate information. This effort is designed to ensure that climate information is used effectively. NOAA, in the Department of Commerce, is the lead agency for this thrust. The flow of information to users will be accelerated, and new institutional arrangements will be established among users, potential users, and suppliers of information, such as State climate offices, Federal agencies, and independent climate experts. Existing extension and information service programs supported by the various Federal agencies will play a key role. A users' advisory group will be established in FY 1980, and the first data inventory will be published in FY 1981. Exploratory efforts to establish a framework for State/Federal cooperation will begin in 1980.

Climate prediction. This thrust includes the development, testing, and implementation of techniques for improved monthly, seasonal, and interannual predictions. The lead agency is NOAA, with major participation by the non-Federal sector through the experimental climate forecast groups. A number of well-conceived approaches to climate prediction will be developed further and evaluated carefully. The first experimental climate forecast group will be established in FY 1980. Operational climate outlooks will be offered in more detail and expressed in probabilistic terms by FY 1981.

This category of activities has two Areas of Program Concern:

Global precipitation measurements. This area involves studies to improve estimates globally of the geographic distribution of precipitation.

Surface climate data networks. This area is concerned with assuring that the observational networks throughout the Nation collect data adequate for regional studies of climate and its impacts.

Responding to Impacts and Policy Implications of Climate

The Principal Thrusts are:

Carbon dioxide, environment, and society. The goal of this thrust is to assess the impacts of the climatic changes that could be caused by continued increases in atmospheric carbon dioxide (CO_2) and to evaluate various amelioration or adaptation strategies. Because increasing CO_2 is associated primarily with the burning of fossil fuels, DOE is the lead agency. Investigations will attempt to determine the timing, magnitude, character, and effects, including the biological and socioeconomic consequences of CO_2-induced climatic changes. A major assessment of the state of knowledge and of the policy options available for future planning will be completed at the end of the 5-year period covered by this Plan.

Climate and world food production. The goal of this thrust is to assess the effect of climate fluctuations on national and world food production, and to use this information in decision making related to the production, storage, trade, and allocation of food resources. The basis for the thrust is ongoing work in USDA and the National Marine Fisheries Service of NOAA. Additional research is proposed for measuring the biological response of livestock and fisheries to climate fluctuations, and testing the use of this information in decision making. USDA will lead an interdepartmental team to determine climate information requirements and capabilities needed to support food production assessments and to prepare detailed management and technical plans. Information resulting from research on livestock and fisheries and their response to climate will begin to be available toward the end of the 5-year period covered by the Plan.

Six Areas of Program Concern are associated with this category:

Climate-related hazards. This area includes assessment of climate-related hazards, studies of hazard processes, and analysis of possible responses to hazardous events.

Energy production, distribution, and demand. This area involves quantifying climate and energy demand relationships, learning how climate affects energy production and distribution, and identifying the constraints and opportunities that climate implies for alternative energy sources such as wind, ocean waves and currents, and solar radiation.

Impact assessment methodologies. This area consists of the development of improved methods for assessing comprehensive climate impacts and efforts to make better use of impact assessment information in decision making.

Regional climate effects of humans. This area includes investigations and observations of physical and chemical processes (such as the particulate-caused Arctic haze) that could lead to regional climate changes, and examinations of the nature and effects of those changes.

Semiarid and arid lands. This area involves developing the information needed for effective management of arid lands, as well as studies to measure the effects of climate fluctuations and extremes on the productivity of these fragile lands.

Water resources management and planning. This area consists of efforts to ensure the appropriate application of climate information to water resources decision making.

Understanding Climate

The two Principal Thrusts are:

Solar and Earth radiation. NASA will lead this effort to clarify the processes by which the climate system gains

and loses radiant energy. This thrust will increase our understanding of the relation between solar variations and climate fluctuations. Analysis of various radiation data sets will advance our knowledge of the stability of the Sun's output, and enhance our understanding of the partitioning of that energy within the climate systems. The simultaneous observations of the different components of the Earth's radiative exchange will lead to improvements in the way climate models relate cloudiness and temperature variations to the radiation budget. Launch of the Earth Radiation Budget Experiment Satellite is planned for FY 1984.

Ocean heat transport and storage. NSF will lead a major, coordinated effort designed to increase our understanding of the ocean's role in climate. Studies will be made on how the oceans redistribute energy within the climate system and how the oceans influence the climate. There will be major advances in making large-scale measurements of ocean currents and temperatures. In FY 1981 heat-flux experiments that will begin in the Atlantic may lead to a series of major international experiments in the late 1980s and early 1990s.

This category has five Areas of Program Concern:

Air-sea interaction. This area encompasses studies designed to understand those large-scale interactions by which these two major components of the climate system are coupled.

Climate model development and validation. This area involves efforts to develop improved climate system models, which are crucial for understanding and predicting climate behavior.

Past climates. This area includes a variety of endeavors to determine the long-term behavior of the climate system and to provide information to use for testing climate models.

Polar ice and snow. This area consists of attempts to study the role of the polar regions in the climate system, and to monitor the response of these sensitive regions to climate change.

Stratospheric processes. This area involves monitoring and research activities designed to provide increased understanding of stratospheric chemical and physical processes, and to detect climatically significant changes.

Total Program Structure

These high-priority efforts are the major initiatives of the first Plan. They are part of a broad array of climate activities in climate impact assessment; climate system research; and data, information, and services. They support, and are supported by, other continuing activities in these areas.

Climate impact assessment identifies procedures to evaluate climate's effects on society, the economy, and the environment in order to develop responses and strategies for dealing with climate fluctuations. Examples of areas included in this category are:

- Industrial and business functions sensitive to climate and the total impact of climate on national and regional economies.
- Ethical and social issues that may be involved in adopting a strategy to deal with climate effects of increasing CO_2.
- Climatic variations and their effects on regional energy needs.

Climate system research seeks to increase knowledge of global and regional climate and its variation. By integrating knowledge of the physical processs and observed behavior of climate, models can be developed that simulate the climate system. These models can then be used to predict and assess the effects on climate of human or natural interference. Examples of areas included in this category are:

- Development of proxy data for reconstruction of past climates where no observational record exists.
- Models of the ocean to understand the role of ocean currents, eddies, and sea ice on climate.
- Systematic studies of climate responses to man-made pollutants.
- Identification of potential limits of climate predictability and of the variables that are most predictable.

Data, information, and services seeks to provide accurate and timely data and information products, responsive to Government and private sector needs. Examples of areas included in this category are:

- Better observations through improvements to operational remote sensing satellites.
- Compilations of experimental data on radiation and trace gases.
- Improvement in forecasts—accuracy, lead time, and information content.
- Evaluation of services.

Special Aspects of the Program

The Plan discusses three special aspects of the Climate Program: international activities, the Intergovernmental Climate Program, and Experimental Climate Forecast Centers.

International activities. International cooperation in climate-related matters is a major aspect of the National Climate Program. Cooperation between nations is essential in collecting and disseminating data, in undertaking research, and in assessing climate impacts. The World Climate Program, consisting of subprograms in research, impact studies, data, and applications, is the major vehicle for such cooperation. Many international bodies have joined this effort, including the World Meteorological Organization, the United Nations Environment Program, and the International Council of Scientific Unions. The United States also engages in bilateral climate cooperation, such as a joint effort with Mexico on arid lands management.

Activities in the U.S. National Climate Program that will contribute to the World Climate Program include: ocean research, climate prediction, research on the international carbon dioxide "problem," and assistance to developing countries in applied climatology.

Intergovernmental Climate Program. The Climate Act requires a program for Federal and State cooperative activities. The Plan outlines a phased development of this program as an integral part of the Principal Thrust in **Generation and Dissemination of Climate Information.** The cooperative efforts outlined in the Plan emphasize the availability and use of local and regional climate information. Information needed to formulate the intergovernmental program and to demonstrate its worth will be acquired starting in FY 1980. Pilot studies will provide the data required for making decisions on the appropriate allocation of costs and responsibilities between the Federal government and the States. Full implementation of the intergovernmental program will depend on the outcome of these studies.

Experimental Climate Forecast Centers. The first experimental climate forecast center will be designated in FY 1980 as part of the Principal Thrust in **Climate Prediction.** The establishment of additional experimental groups is an option for future program development once a better assessment has been made of the effectiveness of such centers. Groups will be selected with a view to their potential for developing innovative approaches to prediction, including concern for tailoring predictions to particular applications of climate information, like energy or agriculture. The experimental forecast centers will also be involved in research on how to improve verifications of climate predictions.

Implementation

The Plan describes program development options for FY 1981 through FY 1984. These are specific activities coupled to the Program's priority areas. The costs of these options are given. The options are ranked in the Plan, the highest ranking ones being those associated with the Principal Thrusts: **Generation and Dissemination of Climate Information**; **Climate Prediction**; and **Carbon Dioxide, Environment, and Society**.

PART I

DEVELOPMENT OF THE CLIMATE PLAN

CHAPTER I

INTRODUCTION

Climate is the way we characterize the weather that occurs at a particular place over periods of weeks, years, centuries, or millenia. The modern notion of climate includes its variations and extremes as well as its average conditions. It also includes the state of the oceans and aspects of the Earth, like the moisture in and on its surface, that influence and vary along with climate.

Over long periods of time, the only constant quality of climate is its constant variability. For most of its several billion years of existence, the Earth seems to have been considerably warmer than it is now. Palm trees were common over the present United States, and giant ferns grew in the areas that are now the Dakotas.

But this mild "normal" climate has been interrupted periodically by glacial periods such as the Pleistocene Ice Age from which we emerged about 10,000 years ago. We are still in a comparatively cold period. Today, both the North and South Poles are covered with ice, but during most of the Earth's history the poles have been ice-free.

Even in comparatively recent times, the climate has varied significantly. From around 1550 to 1850, a long cold spell known as the "Little Ice Age" occurred in much of the Northern Hemisphere. European glaciers grew, and the river Thames at London began to freeze with increasing frequency. Farming became impossible in many parts of the Alps as well as in northern regions such as Iceland and Norway.

Since the late 1800s, most of the world has experienced comparatively mild climatic conditions. But extreme climatic events have occurred. The "Dust Bowl" drought of the 1930s devastated much of the central United States. A spell of bad growing weather around the world in 1972 caused crop failures that had widespread political and economic repercussions, including a controversial agreement between the United States and the Soviet Union for sale of United States grain. Severe winters in much of the United States in 1977 and 1978 threw many people out of work when factories, businesses, and schools closed because of fuel shortages. Droughts in the western part of the Nation threatened agricultural and municipal water supplies.

At the same time, a growing body of scientific evidence indicated that human activities might be affecting the climate in significant ways. Many atmospheric scientists are convinced that increasing amounts of carbon dioxide produced by combustion of fossil fuels such as coal and oil are causing a gradual increase in global temperature, along with other possible effects on climate and other aspects of the environment. One of these effects could be redistribution of rainfall that would affect the productivity of major agricultural regions of the world.

We are not helpless when the climate behaves in unfavorable ways. Proper management and planning can reduce the adverse consequences of such extreme climatic events. Research and information can help us use climate as a resource to aid food production, transportation, and recreation. We have a vast array of tools to observe climatic fluctuations and to assess their effects. We must avoid planning on the assumption that the climate will be constant. We can design our institutions and activities to be resilient to many climatic contingencies. An understanding of the ways in which climate affects people, institutions, plants and animals, land, and water is within our reach today.

Human activities may be changing climate. We must be able to recognize and respond to the impacts of our actions. Changes in temperature and other climatic conditions are likely consequences. Increased burning of fossil fuels, increased injection of dust and ash into the atmosphere, increased emission of sulfur dioxide, and changes in land use may disturb the natural balance in the air and affect cloudiness and precipitation.

We must study the environment to obtain reliable answers to questions about humans' inadvertent influences on climate and to minimize adverse impacts from our future activities. We must learn both how climate behaves and why it behaves as it does. We can apply our knowledge to accommodate effectively to variations in climate.

New technologies that use computers, satellites, and other sophisticated tools are providing opportunities for unprecedented scientific advances. Intellectual resources here and throughout the world are being aimed in new directions in order to make these advances.

This plan points to some of those new directions by proposing a National Climate Program. Its impetus came from the National Climate Program Act enacted by the Congress and signed by the President in 1978. Its future involves cooperation and interaction with the new World Climate Program proposed by the World Climate Conference in February 1979.

A. The National Climate Program Act

A sequence of national and international meetings, studies, and events in the mid-1970s resulted in recommendations for a program to study and use climate—to examine climatic variation, its importance in human activities, and human influences on it. A series of reports (Appendix I) all had a consistent message—more can and should be done. Early recommendations emphasized research and monitoring. More recent recommendations urged more analysis of climate impact and application of climate knowledge.

The reports identified problems and suggested ways of addressing them. A series of climate-related events—drought, cold, and freezes in the brief interval from 1972 to 1978—prompted the Congress to react by passing new legislation in 1978. Both the House Report (Report No. 95-266) and the Senate Report (Report No. 95-740) accompanying the bills that eventually become Public Law 95-367, the National Climate Program Act, cited events such as the 1972-74 drought in the Sahel, the 1972 winter freeze in the Soviet Union, the Peruvian anchovy harvest failures of 1971 and 1973, the 1976-77 drought in the United States, and the severe winter of 1977 in the eastern United States.

The National Climate Program Act (Appendix II) emphasizes the need for a broadly based program to coordinate Federal, State, academic, and private sector efforts; foster better integration of basic and applied research; develop more effective working relations between the producers and users of climate information; and encourage more reliable forecasting of climate and its impacts.

The Act established a National Climate Program "to understand and respond to natural and man-induced processes and their implications," and specified that it should include:

- Assessments of climate impacts on the natural environment, agricultural production, energy supply and demand, land and water resources, transportation, human health, and national security.
- Basic and applied research to improve the understanding of climate and its societal implications.
- Methods for improving climate forecasts on a monthly, seasonal, yearly, or longer basis.
- Global data collection, monitoring, and analysis to provide readily available and useful data on a continuing basis.
- Systems for the management and active dissemination of climate data, information, and assessments, including mechanisms for consulting with current and potential users.
- Measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination.
- Mechanisms for intergovernmental climate-related studies and services.
- Establishment of experimental climate forecast centers.
- Development of a 5-year National Climate Program Plan.

The Program is administered through the National Climate Program Office—the focal point for the planning and coordination of the Nation's climate-related activities. This office establishes program goals, sets priorities, recommends resource allocations, ensures effective participation by nongovernmental groups, defines the roles of various Federal departments and agencies, and evaluates the Program's progress.

The Program is to be guided by a 5-year plan, developed by the National Climate Program Office with the assistance and consultation of all concerned parties. The 5-year plan will serve as a basis for structuring and managing the National Climate Program, and it will be reviewed and extended every 2 years.

B. The First 5-Year Plan

The 1978 Climate Program Act states that the "plan shall establish the goals and priorities for the National Climate Program . . . and shall contain details regarding (A) the role of the Federal agencies in the programs, (B) Federal funding required to enable the Program to achieve such goals, and (C) Program accomplishments that must be achieved to ensure that Program goals are met within the time frame established by the plan."

This 5-year plan responds to that mandate. It is structured to call attention to the most important climate problems and issues, to identify those who have the responsibility to address them, and to note the activities needed to achieve the Program's goals. Priorities are set for the use of existing resources and for planning future resource requests.

Many Federal agencies have had climate research and service programs for a long time. Their missions required that they perform climate research and use climate data and information. Appropriations for direct Federal climate activities totaled $88.1 million in Fiscal Year 1979 and $115 million in Fiscal Year 1980 (table 1). The President's budget request for climate activities for Fiscal Year 1981 is $126.7 million.

Table 1.—Federal Agency Climate Budget

	FY 79	FY 80
	—Million dollars—	
Agriculture	$15.0	$17.1
Commerce	18.2	21.6
Defense	8.0	8.7
Energy	4.5	7.7
Interior	4.2	5.4
NASA	12.9	27.7
NSF	25.3	26.8
Total	$88.1	$115.0

The Climate Plan builds on these existing programs. Many activities now in progress are directly relevant to the National Climate Program. Many agency and Climate Program objectives are identical. Because of special mission responsibilities, Federal agencies support other activities that contribute to Climate Program objectives. The Operational Meteorological Satellite Program of NOAA's National Environmental Satellite Service is such an example.

The Executive Branch and the Congress can use the Plan to guide its oversight of Federal climate activities. State governments can use the Plan to coordinate their activities with Federal ones and to assess their contributions and benefits. Scientists can be guided by the Plan in determining research needs and priorities and in locating Federal agencies that are responsible for activities that interest them.

Meteorologists and climatologists serving the private sector can use the Plan to identify potential new sources of information, to assess such information, and to learn where to direct requests for new data and information. Climatologists and planners in other nations and in international organizations can look to the Plan to identify the scope of the U.S. contribution to the World Climate Program and to assess how their efforts and ours can best mesh. Users of climate information, as well as the public, can look here for a review of current capabilities and future expectations. Finally, the Plan will be used as the basis for administering the Program by the National Climate Program Office, with the help of participating Federal agencies.

The strategy of the Plan is to emphasize early production of useful information based on our knowledge of climate, while simultaneously expanding our understanding of climate. The National Climate Program is divided into three categories:

- Providing Climate Products
- Responding to Impacts and Policy Implications of Climate
- Understanding Climate.

Within each of these categories, priorities are detailed, responsibilities are assigned, and specific activities are suggested. Part One of this Plan introduces the Program. Chapter II explains how priorities were established. The highest priorities are given to six "Principal Thrusts" (table 2). The second level of priorities includes 13 "Areas of Program Concern" (table 3).

These two highest levels of priorities do not constitute the entire Program. The Principal Thrusts and Areas of Program Concern draw upon a much broader program base, and maintaining the health and vigor of that base is essential if the Program is to respond to future needs and concerns. As the Program is conducted, priorities will change, but the priorities at any given time should not be allowed to constrain the range of continuing activities. The Plan must integrate the new initiatives into the overall goals of the Program—to understand and respond to climate.

Table 2.—Principal Thrusts for the National Climate Program

Activity Category	Principal Thrust	Lead Agency
I. Providing Climate Products	Generation and Dissemination of Climate Information	NOAA
	Climate Prediction	NOAA
II. Responding to Impacts and Policy Implications of Climate	Carbon Dioxide, Environment, and Society	DOE
	Climate and World Food Production	USDA
III. Understanding Climate	Solar and Earth Radiation	NASA
	Ocean Heat Transport and Storage	NSF

Table 3.—Areas of Program Concern

Activity Category	Area of Program Concern
I. Providing Climate Products	Global Precipitation Measurements
	Surface Climate Data Networks
II. Responding to Impacts and Policy Implications of Climate	Climate-Related Hazards
	Energy Production, Distribution, and Demand
	Impact Assessment Methodologies
	Regional Climate Effects of Humans
	Semiarid and Arid Lands
	Water Resources Management and Planning
III. Understanding Climate	Air-Sea Interaction
	Climate Model Development and Validation
	Past Climates
	Polar Ice and Snow
	Stratospheric Processes

Options for future program development are suggested in connection with many of the Program's Principal Thrusts and Areas of Program Concern. These options describe activities not included in present agency plans that could be undertaken over the next few years. Some of them emphasize new climate activities; others suggest expanded

efforts in directions that would lead to an overall program balance different from the present one. They are presented at appropriate places in the Plan so that the agencies—which have the program implementation responsibilities—can consider them as they develop their specific plans and resource requests for FY 1982 and beyond. The identification of an option is **not** a request for new resources.

Any option will compete for resources in an agency against its ongoing efforts and against possible agency initiatives. Each option has been assigned a priority in the 5-Year Plan to provide the agencies with a measure of its importance (1) to the goals of the National Climate Program, and (2) to the implementation strategy defined by the Principal Thrusts and Areas of Program Concern.

The dollar figures associated with the various options given in the Plan are preliminary estimates for agency guidance purposes. More accurate costs will be developed by agencies as they develop implementation plans and schedules. Regular budget processes will determine whether any agency will actually request funds for a particular option, and whether these funds will be in addition to or in lieu of continuing climate program resources.

The Plan establishes the structure for climate and climate-related activities by dividing them into three components: **Climate Impact Assessment**, **Climate System Research**, and **Data, Information, and Services** (table 4). The objectives of Climate Impact Assessment are to assess the social implications of climate extremes, fluctuations, and changes and explore options for national and international response actions and strategies. The objectives of Climate System Research are to develop understanding and capabilities for describing climate processes, forecasting climate conditions, and assessing and predicting causes of climate change. The objectives of Data, Information, and Services are to provide products to be used for planning, design, natural resources management, and policy decisions.

Part Two of the Plan describes the 5-Year National Climate Program. Chapters III, IV, and V detail the National Program by activity category and describe the Principal Thrusts and Areas of Program Concern. Chapter VI integrates the detailed priorities of this first Plan into a continuing National Program.

Part Three of the Plan details methods to implement the National Program. Chapter VII looks at three specific Congressional goals for the Program—measures for encouraging and participating in international climate activities; promotion, coordination, and use of intergovernmental (State/Federal) climate activities; and development of experimental climate forecast centers.

Cooperation between nations is essential in collecting and disseminating data, undertaking research, and assessing climate impacts. The World Climate Program, which includes four subprograms (in research, impact studies, data, and applications), is the major vehicle for such cooperation. The National Climate Program draws from and contributes to the World Climate Program in most areas, with special emphasis on ocean research, climate prediction, research on the international carbon dioxide problem, and applied climatology assistance to developing countries.

Table 4—Structure of the National Climate Program

Climate Impact Assessment
- Policy responses and strategies
- Societal implications of climate
- Impacts on economic activities
- Effects on processes and natural resources

Climate System Research
- Empirical studies and analyses of the climatic record
- Development of climate simulation and prediction models
- Studies of physical climate processes

Data, Information, and Services
- Observations
- Data management
- Analysis and prediction
- Information services

The Plan includes a program for Federal and State cooperative activities. A phased development of an intergovernmental climate program is proposed—starting with exploratory projects. These exploratory projects will contribute importantly to implementation of the Principal Thrust of Generation and Dissemination of Climate Information.

The National Climate Program Act requires development of experimental climate forecast centers to encourage the development and testing of innovative approaches to long-range predictions. The Plan proposes establishment of the first center in the last quarter of FY 1980 and others in later years. These centers will be used as part of the implementation of the Principal Thrust of Climate Prediction.

The Centers are to develop innovative approaches to prediction, including concern for tailoring predictions to particular applications of climate information such as energy or agriculture, and to be involved in research on how to improve verification of climate predictions.

Chapter VIII describes how the Program is to be administered—through use of the National Climate Program Office, the Climate Program Policy Board, an Interagency Working Group, an Advisory Committee, and external contacts. Procedures to set a budget and evaluate projects are also described.

Chapter IX indicates the resources and planning needed to implement the Plan. Funding requirements, budget options, and recommendations are given. Preparations already begun to review and extend the Plan are also noted.

C. Federal Agency Climate and Climate-Related Activities

1. Department of Agriculture (USDA), FY 1980—$17.1 million

USDA analyzes and uses climate and weather information extensively in its agriculture and forestry programs. Six USDA agencies carry out climate activities. These activities include research and operational assessments of climate impacts, and applications of impact assessment information and other weather and climate data and information in USDA food, agriculture, and forestry programs.

The Economics, Statistics, and Cooperative Service (ESCS) estimates the effects of weather on agricultural production, farm employment and income, supplies and utilization of food and fiber products, consumer food prices and expenditures, and the use and adequacy of land and water resources. Program activities include publication of the "Weekly Weather and Crop Bulletin" (prepared jointly with the Department of Commerce), crop yield forecasting, near-term outlook and analysis, and seasonal assessments of the effects of weather and climate on domestic and world crop conditions.

The Science and Education Administration (SEA) carries out a broad program of research and extension services to improve agricultural productivity and reduce adverse effects of climate on agricultural systems. Climate-related research is concerned with using and managing water resources for agricultural use; optimizing the use of energy, water, and fertilizer; improving techniques for irrigation and drainage; reducing plant and livestock stress from the environment; improving photosynthesis production and understanding CO_2 cycles; and developing production, management, decision, and tactical models and systems for use in making better management decisions to minimize the adverse effects of weather and climate.

ESCS, the Forest Service, the Soil Conservation Service, the Foreign Agricultural Service, and SEA participate in a joint USDA-NOAA-NASA research program on the application of aerospace technology to meet agricultural information requirements. The interagency program includes research to develop early warning methods and crop yield models that use climatic, environmental, technological, and economic variables affecting plant growth and development and crop yield.

The Foreign Agricultural Service (FAS) monitors and reports on world agricultural production and trade. This requires developing and maintaining information and data on factors, including weather, that affect the production, supply and trade of important world commodities. FAS also has a Crop Condition Assessment (CCA) activity that analyzes LANDSAT, historical, and worldwide weather and climate data to estimate the extent and severity of weather-related events that affect crop production. The results of CCA analyses are made available to FAS commodity analysts, who use them to develop estimates of foreign crop production.

The Forest Service (FS) makes impact assessments to determine direct and indirect relations between climate anomalies and productivity of forest ecosystems. A major FS interest is the relation of weather factors to fire outbreak and its application in management practices for reducing fire hazards on forest lands.

The Soil Conservation Service (SCS) provides technical assistance to individuals or groups in conservation, development, and productive use of the Nation's soil and water resources. Emphasis is placed on long-term impacts of climate in relation to use and management of soil and water resources along with short-term impacts on soil moisture, water supply, and potential for wind erosion. SCS also observes snowpack and related hydrometeorological data on about 1,600 sites in 11 western States and Alaska. The data are used to support water supply forecasts made by States.

The World Food and Agriculture Outlook and Situation Board (WFAOSB) integrates agricultural data and intelligence, including weather and climate conditions, into a coherent picture of the current and future outlook for U.S. and world agricultural and food production. To improve its ability to monitor the most unpredictable element in worldwide agriculture—weather—WFAOSB created the Joint Agricultural Weather Facility in cooperation with NOAA. The facility provides early alerts on major upcoming changes in weather patterns and helps commodity experts determine the probable impact of weather on crop production. The facility compiles meteorological data from 6,500 weather stations around the world, from weather satellites, and from other sources. The estimates that WFAOSB coordinates serve as the official forecasts by USDA in reports released to the public and in material and testimony presented to the Congress.

In 1978, USDA carried out a Weather and Water Allocation Study, at the direction of the Congress, to assess current climate and weather conditions and the possible impact of climate change on future food and feed availability and prices.

2. Department of Commerce (DOC), FY 1980—$21.6 million

The National Oceanic and Atmospheric Administration (NOAA) carries on the DOC climate activities. They range from study of effects of climate and delivery of climate services to observations, data management, and experimental and theoretical studies of the climate system.

The National Marine Fisheries Service (NMFS) is concerned with identifying climate factors that are useful for predicting fishery yields and understanding how the ocean food chain responds to climate events.

The Environmental Data and Information Service (EDIS) also studies climate impact, emphasizing numerous assessments of climate-related energy demand and foreign crop yields in cooperation with the Departments of Agriculture, Energy, and State. The largest EDIS climate activity is the National Climatic Center (NCC). NCC is the principal U.S. archive for climatological data, receiving and processing all U.S. weather observations and records. The functions of NCC include publishing of numerous data periodicals (more than 1 million copies are distributed annually), providing special data summaries and tabulations, and responding to tens of thousands of requests for information annually. NCC collaborates with State climate offices in meeting demands for climate information. NCC also archives satellite data and information products, and provides climate applications and information services to heating and refrigeration engineers, architects, builders, and other groups.

The Environmental Science Information Center is a repository for global climate information and climate publications. Its holdings include long published records of foreign climate data.

The National Oceanographic Data Center (NODC), the world's largest repository of unclassified oceanographic data, and the National Geophysical and Solar-Terrestrial Data Center (NGSDC), which archives data on the upper atmosphere and space environment of the Earth, also perform functions important to the Climate Program.

The National Weather Service (NWS), whose principal function is weather forecasts and warnings, operates a major network of observing stations and communications systems that collect much of the national and international meteorological measurements which form the basis of all climatological analyses. NWS also operates the Climate Analysis Center (CAC) within its National Meteorological Center. CAC has consolidated a number of NOAA activities to attain a more concentrated and better coordinated approach to climate diagnosis and projection. CAC produces a number of regular analyses of global climate conditions based on both satellite and conventional data and, working with USDA, has been expanding the climate information in the "Weekly Weather and Crop Bulletin." This is in addition to issuing monthly and seasonal climate outlooks and supporting statistical and diagnostic studies aimed at improving predictions.

The National Environmental Satellite Service (NESS) operates polar-orbiting and geostationary meteorological satellites that obtain much data of special climatological relevance, such as extent of sea ice and snow and measurements of the Earth radiation budget.

Several of NOAA's Environmental Research Laboratories (ERL) have significant climate programs. The Geophysical Fluid Dynamics Laboratory (GFDL) has a very extensive program, based largely on the use of numerical modeling skills and advanced computational facilities, to study the structure, variability, predictability, stability, and sensitivity of global and regional climate. Through model development, including models of the ocean and of the upper atmosphere, numerical simulation experiments, and careful diagnostic analyses, this laboratory has been producing major contributions to understanding climate. For example, the most frequently quoted analyses of the climatic impact of increasing CO_2 are based on GFDL research.

The Pacific Marine Environment Laboratory (PMEL) and the Atlantic Oceanographic and Meteorological Laboratory (AOML) are pursuing studies to identify and understand ocean processes that contribute to year-to-year climate changes. A measurement program begun last year as part of the Equatorial Pacific Ocean Climate Studies (EPOCS) is the first step in a comprehensive effort to understand ocean variability.

The Geophysical Monitoring for Climate Change (GMCC) program of the Air Resources Laboratory (ARL) operates four "baseline" or "clean air" stations that monitor atmospheric constituents to assist in determining the influence of trace gases and particulates, both natural and from human activities, on global climate. Among the constituents measured are ozone, carbon dioxide and fluorocarbons. GMCC also has a somewhat broader ozone-observing program.

Other ERL programs are related to the chemistry and physics of stratospheric processes (e.g., ozone, fluorocarbons), climatically significant tropospheric phenomena (e.g., radiative transfer and aerosols), and the behavior of polar ice sheets.

The Office of Ocean Engineering (OOE) and the Global Atmospheric Research Program (GARP) Office also are active in climate. OOE has been developing and testing buoys of several different characteristics for use in climate research and monitoring. Drifting buoys demonstrated their great value for climate research in the Global Weather Experiment, as did air-dropped, polar-drifting buoys. The GARP Office was lead agency for U.S. participation in the Global Weather Experiment which, in addition to the buoy programs, included many other extensive observing programs. The data sets emerging from the Experiment and the research to be supported as part of GARP are directed, to a great extent, to understanding the physical basis of climate.

3. Department of Defense (DOD), FY 1980—$8.7 million

DOD must plan and conduct operations in all climatic conditions. Consquently, it supports a variety of mission-related climate activities that are extremely important to the National Climate Program. The activities include observing the weather/environments, assembling climatic data and information and applying that information to defense needs, and undertaking research on the processes that regulate climate.

DOD makes meteorological and oceanographic observations at many locations around the world and operates communications systems that disseminate global data to military weather activities as well as to NWS. These are important components of the assembly of climatological data bases. In addition, DOD meteorological rocketsonde and satellite programs feed important environmental information into the national data base. DOD analyses of global cloudiness and oceanographic conditions are particularly useful. DOD also operates a significant part of the Nation's river-gaging and precipitation-observing networks.

Several DOD facilities makes major efforts to understand the impact of climate on military plans and operations. Most important in this regard are the Air Force Environmental Technical Applications Center, (USAFETAC), the Navy Fleet Numerical Oceanographic Center, and the Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL). DOD has processed and assembled extensive data compilations that are available to civilian users through NOAA/EDIS data centers. DOD also publishes numerous analyses and compilations of information bearing on climate and climate variability (e.g., ice atlases and charts).

DOD has participated significantly in several areas of climate research. DOD has been particularly active in research programs aimed at understanding the roles of the oceans and the cryosphere in climate. DOD has joined NSF in supporting several major projects, including the North Pacific Experiment (NORPAX), designed to study the climatic causes and effects of large-scale temperature anomalies; the Polygon-Mid-Ocean Dynamics Experiment (POLYMODE), an investigation of mesoscale oceanic eddies; and the Indian Ocean Experiment (INDEX), designed to analyze oceanic circulation and its response to large-scale atmospheric forcing. CRREL conducts significant research on sea ice and ice sheets and their role in climate.

4. Department of Energy (DOE), FY 1980—$7.7 million

DOE's climate-related activities are tied to the relationship between climate and energy production and distribution, including both the effect of climate on energy production and demand and the effect of energy-related activities on climate. Two key issues are highlighted in the DOE program: (1) the profound set of relationships among the combustion of fossil fuels, increasing atmospheric carbon dioxide, and the resulting potential long-term effects on climate, the environment, and society; and (2) the immediate pragmatic concern for improving methods of fuel management through the better use of climate knowledge and information.

DOE has responded to the CO_2 issue through a vigorous program led by the CO_2 Effects and Assessment Office, which was established within the Office of the Assistant Secretary for Environment. The basic aim of this program is to develop the ability to predict the agricultural, environmental, and societal consequences, both national and international, of increasing atmospheric concentrations of carbon dioxide, with sufficient confidence to permit informed policy decisions to be made on the use and development of energy and other resources. An extensive research and assessment program has begun on the effects of increasing CO_2 on climate, on the effects of climate change and the CO_2 increase on other aspects of the environment, and on the social and economic consequences of CO_2-induced changes. The program includes research on the global carbon cycle and the amelioration of impacts, and will review, integrate, and evaluate the research and its outputs. Initial work is well underway on many aspects of climate research, especially those related to carbon cycle studies and climatic effects. Specific projects include studies of the sizes and dynamics of various CO_2 reservoirs (e.g., oceans, biosphere); reconstruction of past climate and CO_2 concentrations using paleographic techniques; and models of the sensitivity of climate changes to CO_2 variations.

DOE is particularly concerned with the use of monthly and seasonal forecasts to manage or schedule fuel production, storage, transportation, and allocation. DOE is working with NOAA to determine better ways of structuring forecasts to make them more useful, and to guide the development of new improved forecast products.

DOE also has studies on potential climatic consequences of substances emitted in power production. Emissions considered include heat, moisture, and various trace gases and particles. Another program is aimed at examining the spatial and temporal variation of haze seen in the eastern half of the United States, which appears to be due to fossil fuel combustion.

DOE also supports various observational programs, some concerned with CO_2, but others involving solar radiation at the ground.

5. Department of the Interior (DOI), FY 1980—$5.4 million

The DOI's U.S. Geological Survey (USGS) carries on a wide range of climate-related work. The Survey's climate program has two main thrusts: (1) monitoring, studying, and predicting the response of various land and water resources to climatic change; and (2) collecting and analyzing information on past climates in order to improve understanding of climate dynamics.

USGS monitors and studies the relations of climatic factors to streamflows, lake and reservoir levels, groundwater tables, erosion rates, landform changes, sedimentation patterns, glacier movements, permafrost distributions, and coastal processes. Climatic influences on the probability of occurrence of natural hazards, such as floods and land-

slides, are also being investigated. Studies are underway to examine the impact of climate and possible climatic changes on the reclamation of strip-mined lands and the selection of suitable sites for disposing of nuclear wastes. Remote sensing data from satellites and aircraft are used to monitor seasonal and yearly changes in glaciers, snow cover, vegetation, and land use. The interaction of human land-use patterns with climate is being studied. USGS cooperates with NOAA/EDIS and its data centers in handling various types of glaciological and other data.

Most hydrological studies involve the use and/or production of climate-related data. The hydrologic cycle and climate are being investigated using various approaches including measuring and studying the stable isotope composition of water. USGS has responsibility for coordinating all Federal water-related data collection, analysis and dissemination, and issues periodic compilations of such information.

USGS has a diverse program that generates valuable information on past climates and their impacts on geologic, hydrologic, and biologic systems. This paleoclimatic research facilitates studying the causes, dynamics, frequencies, and magnitudes of natural climatic changes—over periods ranging from decades to eons. The relations of volcanic eruptions to climate change, the carbon cycle, and long-term changes in the CO_2 content of the atmosphere are under study.

The Bureau of Land Management (BLM) is involved in a variety of studies of climate as one factor in the management of forest, land, and water resources. The Office of Water Research and Technology does considerable hydrologic research and the National Park Service is concerned with the impact of climate on wildlife, water, and air quality. Projects of the Water and Power Resources Service relate climatic factors to water management, weather modification, and potential use of solar and wind energy.

6. National Aeronautics and Space Administration (NASA), FY 1980—$27.7 million

NASA has embarked on a broad climate research program. Its principal goals are to develop a capability for observing global climate from space and to contribute to understanding of the processes that influence climate and its predictibility. The four principal areas of NASA climate program activity are data-base development, special studies, climate modeling and analysis, and development of a climate-observing system.

Data-base development involves extensive processing of data acquired from space platforms, often in conjunction with more conventional data, to facilitate their use and to demonstrate the value of space data for climate applications and studies. Examples include global data sets on aerosols, Arctic and Antarctic sea ice, precipitation over the oceans, and Earth radiation budget.

Special studies, in which observational efforts and analytical and theoretical studies are aggregated, are undertaken to gain insight and understanding of physical processes and connections among climate variables, to develop parameterizations for numerical climate models, and to aid in future remote sensor development. Some current examples include studies of polar ice, precipitation, and soil moisture processes in conjunction with microwave observations from space, and of cloud processes and parameterizations related to interpreting radiation budget measurements.

NASA develops climate modeling capabilities to guide the design of space-observing systems and to optimize the use of space-acquired data. These modeling capabilities are important in assessing climate predictability and understanding climate sensitivity. NASA climate models have been useful tools for assessing the response of climate to changes in atmospheric CO_2 and surface reflectivity.

NASA's principal contribution to the National Climate Program is the development of space-observing systems for use in climate research and climate monitoring. This also includes improving NOAA's operational meteorological satellite system. The principal current effort is development of the Earth Radiation Budget Experiment, the Nation's first satellite system dedicated to climate research. Other ongoing key activities relate to developing and testing remote sensors for observing precipitation, aerosols and trace gases in the stratosphere, ocean surface conditions, and numerous other important climate variables.

7. National Science Foundation (NSF), FY 1980—$26.8 million

NSF provides major support for U.S. research on climate and climate-related subjects. The support, through several NSF divisions, covers efforts in research, specialized observations associated with the research, and costs associated with operations of ships and facilities. Climate research is sponsored through grants to support individual scientists or institutions, and also through extensive collaborative research programs. Many of the collaborative projects involve extensive international participation.

Of particular interest to climate research are several major programs that evolved within the frameworks of the Global Atmospheric Research Program (GARP) and the International Decade of Ocean Exploration (IDOE). Under GARP, NSF has been concerned particularly with U.S. participation in the Monsoon Experiment (MONEX) and has supported significant observing programs and research associated with the Global Weather Experiment. Within recent years, several major IDOE programs have been significant parts of the national effort to study oceanographic aspects of climate. These include the Polygon-Mid-Ocean Dynamics Experiment (POLYMODE); ISOS, an investigation of the circumpolar flow around the Antarctic continent; the North Pacific Experiment (NORPAX), a study of large-scale temperature features of the Pacific Ocean and their relation to atmospheric climate; and GEOSECS, an investigation of the geochemistry of the world oceans to gain insights into large-scale mixing and exchange processes.

NSF supports major climate modeling efforts in the academic community and at the National Center for Atmospheric Research (NCAR). The climate models being developed, extended, and verified include general atmospheric circulation, oceanic circulation, coupled ocean-atmosphere, and highly simplified ones. Model testing includes the use of data on past climates, and research on the ability of the model to simulate the observed climate over the seasonal cycle and to infer the sensitivity of climate to increases in atmospheric carbon dioxide.

NSF provides significant support for studies of past climates obtained by "proxy" measurements such as tree ring studies, analyses of ocean sediments and ice cores, and pollen distributions in lake sediments. Such climate data sets provide long-term statistics on the inherent variability of climate.

NSF also supports investigations of the influence of climate on human affairs, particularly in agricultural production and in energy and water management.

8. Department of Transportation (DOT)

DOT has no major mission directly related to climate. However, it is actively involved in numerous climate-related activities. The Federal Aviation Administration (FAA), for example, is responsible for taking meteorological observations at many airports throughout the country, and conducts and supports applied local climatological studies for use as airport forecast aids and for airport planning.

Through its High Altitude Pollution Program (HAPP), FAA has studied the effect on the stratosphere of effluents from high-flying airplanes. Trace chemicals as well as ozone and water vapor in the stratosphere have been measured. These data are being analyzed and interpreted.

The Federal Highway Administration does research on environmental factors related to highway design, in terms of both climatic conditions affecting highways and the future impact of highways and their traffic on the local environment.

For over 150 years, the U.S. Coast Guard (USCG) has acquired marine meteorological, oceanographic, and sea ice data. USCG also makes aerial reconnaissances of Great Lakes ice growth and decay, and of migration of Grand Banks icebergs into the North Atlantic shipping lanes. Based on historical data, long-term trends and seasonal predictions are made to develop operational plans.

9. Environmental Protection Agency (EPA)

EPA has developed a broad base of climatic knowledge and technical capabilities, because of its mission objectives to protect and regulate the quality of the air and water.

EPA sponsors the Stratospheric Modification Impact Research Program, which involves monitoring ultraviolet (UV) radiation and stratospheric ozone levels. This program includes study of biological effects of increased UV radiation, as well as work on instrumentation support and integrated impact assessment.

EPA is also making a national assessment of the acid rain problem with particular emphasis on long-term impacts on forests, agriculture, and aquatic ecosystems. Other EPA projects involve the long-term transport and fate of atmospheric pollutants (such as sulfur and fine particulates) that produce haze and may affect precipitation and the Earth's radiation balance. EPA has also studied economic and societal impacts associated with regulatory actions and has developed methodologies that may be useful for studying effects of climate change.

10. Federal Emergency Management Agency (FEMA)

FEMA provides a central management focus for Federal emergency planning and response. FEMA assists State and local governments in planning and taking actions to mitigate the impact of all types of natural disasters, including climatic hazards such as droughts, and other environmental changes with potential major impacts. In planning and carrying out these functions,FEMA is directly concerned with environmental assessment and outlooks and their long-term social and economic significance.

11. Department of State (DOS)

DOS's continuing mission is to facilitate international cooperation and secure the foreign policy objectives of the U.S. Government. In regard to climate activities, that role involves securing participation by U.S. agencies in the research, data gathering, and monitoring activities of international organizations, especially the United Nations and its specialized agencies; establishing bilateral cooperation with foreign governments; and designating U.S. representatives to attend intergovernmental meetings and conferences related to climate to assure consistency and coordination of these activities.

CHAPTER II

ESTABLISHING PRIORITIES

An extensive array of Federal climate activities exists as a foundation for the National Climate Program. The selection of priorities for the first 5-year period of the National Climate Program was guided by the Act, by assessing the ability and readiness of certain agencies to undertake particular activities, and by recommendations from various groups, especially the National Academy of Sciences. The priority efforts are focused on some areas in which Federal agencies have been quite active as well as on others in which new efforts will have to be developed. For example, Federal programs relating to the impact of climate on agriculture, the effects of increasing atmospheric CO_2, and observations of the Earth's radiation balance have expanded substantially. Other areas, such as climate prediction, have grown only modestly or not at all.

One of the most significant sets of recommendations the National Climate Program has received was "A Strategy for the National Climate Program" (Climate Research Board 1979), the result of a Climate Research Board, National Research Council workshop in July 1979. The principal recommendation was:

> The National Climate Program should emphasize early production of useful outputs on the basis of our present knowledge of climate, while simultaneously expanding the understanding of climate and its relationship to society.

This basic recommendation is consistent with the statutory dual purpose, "to understand and respond." Priority efforts are identified in this Plan within three categories that correspond to this recommendation. They are:

- Providing climate products.
- Responding to impacts and policy implications of climate.
- Understanding climate.

The highest priority efforts in each of these categories are referred to as **Principal Thrusts.** These are areas of major importance to the goals of the Climate Program. Principal Thrusts are centered on subjects that are important and that also offer a significant opportunity for measurable progress. Most Principal Thrusts call for multiagency, multidisciplinary, and multitask efforts. Because of their importance and complexity, they warrant special attention with regard to management as well as funding. Thus a lead agency is designated to coordinate both planning and implementation for each Principal Thrust.

The Principal Thrusts do not constitute all the very important activities within the Climate Program. A second tier of issues (**Areas of Program Concern**) is not as urgent as the Principal Thrusts, but still warrants serious attention when assigning resources. An Area of Program Concern may reflect an issue of great importance some years hence, but its urgency is not yet firmly established. It may be a Principal Thrust that is no longer urgent. It may relate to a relatively obscure aspect of the Program which has lacked support and which now threatens to hamper progress elsewhere. Because of a relative lack of urgency, Areas of Program Concern will usually involve fewer peripheral activities and thus will be more narrowly defined than Principal Thrusts.

The Principal Thrusts and Areas of Program Concern, as the highest priority efforts of the Climate Program, are not the entire program. A total program must integrate Principal Thrusts and Areas of Program Concern with other continuing activities that support the Program's objectives of understanding and responding to climate. The Climate Program will encourage agencies to develop new methods and strategies—using new initiatives and continuing activities—to improve (1) **climate impact assessments**, (2) **climate system research**, and (3) **data, information, and services.**

A. Statutory Elements

Section 5 of the National Climate Program Act defines nine elements that are to be included in the National Program. Five deal with programmatic directions and content. Four relate to how the program should be carried out. The National Climate Program responds to these mandates in this Plan.

1. Assessment of Effects of Climate—Section 5(d)(1)

The Program is to include:

> "(1) assessments of the effect of climate on the natural environment, agricultural production, energy supply and demand, land and water resources, transportation, human health and national security. Such assessments shall be conducted to the maximum extent possible by those Federal agencies having national programs in food, fiber, raw materials, energy, transportation, land and water management, and other such responsibilities, in accordance with existing laws and regulations. Where appropriate such assessments may include recommendations for action . . . ."

The Departments of Agriculture, Commerce, Defense, Energy, and the Interior have active assessment programs. USDA has expanded its research on crop yield modeling as part of an interdepartmental program to apply aerospace technology to agricultural uses. USDA also has supported research for many years on climate and weather

effects on crops, animals, soils, forests, and water resources. DOC, through NOAA, cooperates in these assessment activities. Climate impact is considered in water resource planning activities, for example by the Army Corps of Engineers and DOI's Water and Power Resources Service. DOD has a well-developed process for assessing climate impacts to support its requirements and operations under a wide variety of operating conditions. For instance, climate statistics are used to select appropriate sites for field testing of aircraft and vehicles, storm track statistics are used to designate safe havens for ships at sea, and cloud cover and ceiling height data are used in the deployment of optically guided field artillery. The DOE impact assessment effort deals with the consequences of climate changes that may result from the increase in CO_2 and with energy demand modeling.

Activities recommended in response to this provision are included under the major initiative category of Responding to Impacts and Policy Implications of Climate and under the Program category of Climate Impact Assessment.

Climate and World Food Production, which is established as a Principal Thrust of the National Climate Program, is aimed toward understanding the impact of climate variations on world food production and using that understanding to make better decisions on production, trade, management, and allocation. Although the study of climate impacts on food production and the active use of climate information in managing food supplies are in early stages of development, they are already bearing fruit. The great importance of food to the economic well-being of the United States and the important role of U.S. food exports in feeding hungry people in many parts of the world make this a subject that will remain important. The lead agency for this activity is USDA, with NOAA as a major participant.

In addition, assessment activities are addressed in four Areas of Program Concern:

- Climate-related hazards.
- Energy production, distribution, and demand.
- Semiarid and arid lands.
- Water resources management and planning.

Finally, under the Program category of Impact Assessment, continuing efforts are proposed for transportation, human health, and national security.

2. Research—Section 5(d)(2)

The Program is to include:

> "(2) basic and applied research to improve the understanding of climate processes, natural and man-induced, and the social, economic, and political implications of climate change . . . ."

Research on climate processes is being actively pursued by several agencies, primarily NASA, NSF, and NOAA. Extensive efforts are underway to develop and test numerical models of climate behavior. Several very large international efforts have taken place to study various climate processes and to develop global data sets that would support climate research. Some particular research deficiencies that were noted earlier by Federal committees or National Academy of Sciences groups are now being addressed, particularly in areas involving the Earth's radiation budget and the ocean's role in climate.

Increasing attention is being given to the influence of human activities on climate. Several recent analyses have reinforced the scientific basis for expecting increasing amounts of atmospheric CO_2 to influence climate. The most critical problem is defining the specific climatic response to increased CO_2. The required research—especially model development and programs to understand some of the important physical processes—is in progress. Research on the biological and geochemical processes of the global carbon cycle is needed to predict how rapidly CO_2 will increase in the atmosphere, but research activity has lagged in this important area.

The attention being given to the CO_2 problem has stimulated interest in the social, economic, and political implications of climate change. Several conferences and planning efforts have resulted, and a community is developing to address research needs in this area. Research should be underway by late FY 1980.

The statutory provision calls for research both to understand climate and to understand the implications of climate and climate change. Strong Federal research programs designed to improve our understanding of climate now exist, but not much research has been done on implications, although new efforts are emerging. Activities recommended in response to this provision are included in several initiatives and program categories. The Climate Program establishes as Principal Thrusts: (1) Carbon Dioxide, Environment, and Society; (2) Solar and Earth Radiation; and (3) Ocean Heat Transport and Storage.

Carbon Dioxide, Environment, and Society deals with predicting and assessing the environmental, economic, and social implications of increasing concentrations of atmospheric CO_2. The CO_2 issue is potentially the most critical environmental issue this generation will encounter and, with its broad ramifications for energy policy, it looms as a major international political issue. This issue has been explored in Congressional hearings on energy policy and in numerous scientific reports. The World Climate Conference of February 1979 drew particular attention to it, and later in 1979 a panel of the National Academy of Sciences (Climate Research Board, 1979b) reiterated the scientific basis for concern. DOE, which has been pursuing the issue vigorously, is lead agency for this Principal Thrust. This major interagency effort includes significant participation by USDA, NSF, and NOAA, among others.

Solar and Earth Radiation involves measuring and understanding the solar energy input to the climate system and the manner in which the Earth absorbs and reradiates that energy. According to one earlier planning document, "A United States Climate Program Plan" (Interdepartmental Committee for Atmospheric Sciences, 1977), observing the Earth's radiation budget is the highest priority observa-

tional requirement for climate research. Solar radiation and the Earth's radiation back to space play critical roles in natural climate variability. They must be understood in order to answer important questions related to climate prediction and inadvertent climate modification by separating effects of varying external influences from those that are products of the internal mechanisms of the climate system. The lead agency for this thrust is NASA.

Ocean Heat Transport and Storage concerns the measurement and understanding of the ocean's role in redistributing energy and thus exercising a large measure of control over the behavior of the entire climate system. Earlier recommendations have all emphasized the important role of the ocean in climate behavior, but only recently have the possibilities for making adequate measurements made this particular critical effort feasible. The continued development of measurement capabilities will be an integral part of this thrust. A number of national and international activities in ocean-climate research are underway and should contribute to these studies. NSF has accepted lead agency responsibility and will receive strong program support from NOAA.

Seven Areas of Program Concern related to climate and impact research are identified as major research initiatives:

- Air-sea interaction.
- Development and validation of climate models.
- Past climates.
- Polar ice and snow.
- Stratospheric processes.
- Impact assessment methodologies.
- Regional climate effects of humans.

Under the program categories of **Climate System Research** and **Climate Impact Assessment** additional activities are proposed to provide comprehensive and accurate descriptions of climate processes and of human and natural causes of climate change, and the societal and environmental implications of such changes.

3. Climate Forecasting—Section 5(d)(3)

The Program is to include:

> "(3) methods for improving climate forecasts on a monthly, seasonal, yearly, and longer basis . . . ."

The third prescribed element of the Program is to develop methods for improving climate forecasts. Existing activities have not concentrated on this area. NASA, NSF, and NOAA support some research on improving climate prediction, but most of it is not immediately applicable to the short-term improvement of climate forecasts. The NOAA Climate Analysis Center, which issues the Government's official predictions, has a growing effort to improve its products.

Activities in the Plan responsive to this provision are included under the Principal Thrusts of Climate Prediction, which is part of the major initiative category of Providing Climate Products, and Analysis and Projection, which is part of the Program category of Data, Information, and Services.

Climate Prediction involves developing, testing, and, where appropriate, implementing innovative ideas for improved monthly, seasonal, and interannual predictions. Predictions have always been in demand by those who use climate information and by many who would use predictive information if it were available. Nevertheless, climate prediction has been a source of concern for the scientists who must produce the forecasts. Advances in the ability to make climate predictions will come slowly. Still, there are many untested ideas, and the great potential benefits warrant a vigorous effort to explore them. The lead agency for this Principal Thrust is NOAA. The program depends most heavily on the efforts of the Climate Analysis Center of the National Weather Service. A number of participating research institutions or universities will be designated as Experimental Climate Forecasting Groups. DOD will also participate.

As part of the Program category **Data, Information, and Services**, continuing activities are recommended to improve climate forecasts through analyses and projections. Proposals are made on handling and analyzing current information, diagnosing anomalies, and improving forecasts.

Finally, improved forecasts are the eventual intended result of many other activities suggested in the Plan. For example, research on solar and Earth radiation and other efforts to improve knowledge of the climate system are part of a long-term effort that may lead to reliable forecasts of monthly to interannual climate conditions.

4. Global Data Collection, Monitoring, and Analysis—Section 5(d)(4)

The Program is to include:

> "(4) global data collection, and monitoring and analysis activities to provide reliable, useful and readily available information on a continuing basis . . . ."

At present global data collection is very extensive. It involves major satellite programs and relies heavily on international exchanges of meteorological data through the World Meteorological Organization's Global Telecommunications System. It has also been stimulated by the very successful Global Weather Experiment. Some observing systems that were introduced to support the experiment may be continued on an operational basis (e.g., buoys, reporting via polar-orbiting satellites; and commercial aircraft, reporting via geostationary satellites). Some recognized deficiencies in global data—particularly precipitation and radiation data—remain.

Available climate data are not always quickly or thoroughly analyzed. For example, some stratospheric data are not being analyzed promptly. The consolidation of several NOAA activities in the Climate Analysis Center has improved the availability of reliable and useful data, and the reports of the NOAA Climate Diagnostic Workshops (National Oceanic and Atmospheric Administration, 1976, 1977, and 1978) illustrate the interest in and value of such analyses.

The Plan recommends a series of activities under numerous categories. Particular emphasis on global data collection,

monitoring, and analysis is detailed in Principal Thrusts and Areas of Program Concern in the activity categories of Understanding Climate and Responding to Impacts and Policy Implications of Climate. For example, analyses of global data are needed for the Principal Thrust of Climate and World Food Production and the Program Concern of Energy Production, Distribution, and Demand. Similarly, global coverage is mandated by the Principal Thrust of Generation and Dissemination of Climate Information and the Program Concern of Global Precipitation Measurements. Other global activities called for in the Program are included in the Data, Information, and Services component. Chapter VI describes the implementation of these and other international Program activities.

5. Data and Information Management and Dissemination —Section 5(d)(5)

The Program is to include:

> "(5) systems for the management and active dissemination of climatological data, information and assessments, including mechanisms for consultation with current and potential users;"

The principal Federal civil activities in this area are the programs of the National Climatic Center (NCC) of NOAA/EDIS. The Center's extensive collections of records and system of data management are being modernized, but this process still has far to go. Current planning at NCC recognizes that the ready availability of data sets and analyses is a key function of the data management system. Dissemination of information through an extensive publication program is useful, but it clearly is not the "active" dissemination the Congress had in mind. NCC has held a limited program of seminars with user groups, but much contact with individual (civilian) users is through private climatologists and meteorologists and State climatologists. There are only small Federal efforts to encourage those contacts.

Activities responsive to this provision are included under the Principal Thrust of Generation and Dissemination of Climate Information within the major initiative category of Providing Climate Products, as well as under the data management and information service elements of the Program category Data, Information, and Services.

Generation and Dissemination of Climate Information is a Principal Thrust directed at assuring that climate data are available, are useful, and are used. Greater efforts are essential if the Climate Program is to comply with Congressional intent and respond to the relevant recommendations of the National Advisory Committee on Oceans and Atmosphere, the Climate Research Board, and other advisory groups. These groups have emphasized the potential benefits of applying climate information to local and regional problems. The main issue is how to provide climate information and services most effectively. The Program will explore a variety of ways of generating and disseminating useful climate information. Many groups will be involved in this effort. NOAA will be the lead agency, with many responsibilities falling to the National Climatic Center. The State climate programs will necessarily play a crucial role. The effort will also involve all the agencies that provide advisory services to which climate information is relevant (e.g., USDA and DOI). DOD will also be involved, especially by providing a useful model for an improved civilian effort.

In addition to this Principal Thrust, supporting activities are detailed in the Data, Information, and Services component of the Program. These activities include:

- Acquisition, maintenance of quality, and archiving of the climatic record.
- Development of interpretations of present climate conditions and estimates of future conditions.
- Delivery of suitably processed data and climate information responsive to user needs.

In the final analysis, responsiveness to climate depends on information about climate and the impacts of climate being available to and understood by officials, managers, designers, planners, and other decision-makers. A structure is proposed that identifies users and establishes rapport between the supplier and consumer of the information. This structure will be based, in large measure, on cooperative Federal/State programs, with the State programs helping to link the producers of climate information and the users.

6. International Cooperation—Section 5(d)(6)

The Program is to include:

> "(6) measures for increasing international cooperation in climate research, monitoring, analysis and data dissemination;"

A great deal of climate research, analysis, and distribution of data and information is already being done on a cooperative worldwide basis. These international efforts were given added impetus when the World Climate Conference in February of 1979 urged a new World Climate Program. The Program was established later that year as a result of actions taken at the Eighth Congress of the World Meteorological Organization (WMO). The U.S. National Climate Program uses and contributes to each of the World Program's four subcategories—the World Climate Research Program, the World Climate Impact Studies Program, the World Climate Applications Program, and the World Climate Data Program. In addition, the agencies given responsibility for activities by this Plan are given specific responsibility for international aspects. Finally, the National Climate Program Office will provide direct support for international programs in a series of program areas. References to international activity appear throughout the description of the Program. Particular attention to the U.S. effort to ensure international cooperation is detailed in Chapter VII.

7. Intergovernmental Activities—Section 5(d)(7)

The Program is to include:

> "(7) mechanisms for intergovernmental climate-related studies and services including participation by universities, the private sector and others concerned with

applied research and advisory services;"

Many States, recognizing needs for climate-related services, have initiated State-supported programs in climate information, dissemination and/or studies tailored to State needs.

Over the past 5 years, active programs in at least 12 States have documented significant increases in the use of climate information. For example, the annual number of requests for climate information in Iowa reached 5,000 after only 2 years of program operation. Among the requestors were 15 different Federal agencies. The active programs serve multicounty planning groups; State agencies; Federal regional and field offices; agricultural, energy, water resources, and transportation interests; and the general public.

In addition to the 12 most active State programs, about 30 States support part-time climate programs that render limited climate information services as time and resources permit. During 1979, several of these States upgraded their climate programs to full-time status.

NOAA's Environmental Data and Information Service (EDIS) has the Federal responsibility for providing climatic data and information services to the civilian sector of the economy. Most of this responsibility will go to the National Climatic Center (NCC) in Asheville, N.C., which annually receives about 70,000 requests for climate information. The annual rate of increase has been 4 to 7 percent.

At present, NCC earmarks up to $25,000 annually to cover the cost of furnishing climatic data and information required by cooperating State Climatologists. The State Climatologists reciprocate by helping prepare routine Federal releases and publications and by handling large numbers of information requests that might otherwise be addressed to NCC or to NWS forecast offices. The State Climatologists responsible for the local services have organized the American Association of State Climatologists (AASC) in order to exchange information and address technical problems of mutual concern.

Most of the States with active full-time climate programs have developed computerized local data archives. Other States are experimenting with modern communications and data-processing facilities to provide services at low cost. Beginning in late 1979, EDIS is funding a pilot project with the Oklahoma State Climatologist to examine a small-system approach that many States could adopt, and to evaluate its potential service- and cost-effectiveness. The pilot project envisions early participation by a few other western States to assess the feasibility of expanding the system into a regional or national system.

The Principal Thrust that involves State/Federal activity is the Generation and Dissemination of Climate Information. To use State capabilities effectively and promote increased intergovernmental studies and services, the Program proposes a phased program to provide for intergovernmental activity in data acquisition and analysis, climate information services, and the study of climate effects.

8. Experimental Climate Forecast Centers—Section 5(d)(8)

The Program is to include:

> "(8) experimental climate forecast centers, which shall (A) be responsible for making and routinely updating experimental climate forecasts of a monthly, seasonal, annual, and longer nature, based on a variety of experimental techniques; (B) establish procedures to have forecasts reviewed and their accuracy evaluated; and (C) protect against premature reliance on such experimental forecasts;"

The Program designates such centers or groups as part of the Principal Thrust of Climate Prediction. Various investigators are using several approaches to climate prediction. The experimental climate forecast program will evaluate the utility of these approaches; improved predictions are expected in 5 to 10 years. The Experimental Climate Forecast Program will also seek development of new measures to verify forecasts. Proposals for participation will be solicited from non-Federal centers of climate expertise. The first center is proposed for the end of Fiscal Year 1980, with plans to develop a total of four by Fiscal Year 1983.

9. The 5-Year Plan—Section 5(d)(9)

The Program is to include:

> "(9) a preliminary 5-year plan, to be submitted to the Congress for review and comment, not later than 180 days after the enactment of this Act, and a final 5-year plan to be submitted to the Congress not later than 1 year after the enactment of this Act, that shall be reviewed and extended biennially. Each plan shall establish the goals and priorities for the Program, including the intergovernmental program under section 6, over the subsequent 5-year period, and shall contain details regarding (A) the role of Federal agencies in the programs, (B) Federal funding required to enable the Program to achieve such goals, and (C) Program accomplishments that must be achieved to ensure that Program goals are met within the time frame established by the Plan."

This document is the final Plan. Chapter IX of this document discusses the updating of this plan on a continuing basis.

B. Program Integration

The Program comprises an array of activities that are divided into three Program components: **Climate Impact Assessment**; **Climate System Research**; and **Data, Information, and Services**. Major initiatives are designated as Principal Thrusts and Areas of Program Concern. These are divided into three categories: **Products**, **Response**, and **Understanding**. Many of these initiatives involve activities in more than one program component. They have been selected because of their importance today.

Table 5.—Relations among Program priority Efforts and Program Components. Asterisks denote important association (see text)

	PRINCIPAL THRUSTS						AREAS OF PROGRAM CONCERN												
	PRODUCTS		RESPONSE		UNDERSTANDING		PRODUCTS	RESPONSE						UNDERSTANDING					
IMPACT ASSESSMENT	INFORMATION	PREDICTION	CO_2	FOOD	RADIATION	OCEAN HEAT	PRECIPITATION	SURFACE NETWORKS	ASSESSMENT METHODS	HAZARDS	ENERGY	REGIONAL EFFECTS	SEMIARID	WATER RESOURCES	AIR-SEA	CLIMATE MODELS	PAST CLIMATES	ICE AND SNOW	STRATOSPHERE
Policy Responses and Strategies	*	*	*	*					*	*	*	*	*	*					*
Societal Implications of Climate			*	*					*			*	*	*					
Impacts on Economic Activities	*		*	*				*	*	*	*	*		*			*		
Effects on Processes and Natural Resources	*		*	*			*	*	*	*	*	*	*	*			*		
CLIMATE SYSTEM RESEARCH																			
Empirical Studies and Analyses of the Climatic Record																			
Historical and proxy data			*							*			*	*			*		
Analytic techniques		*								*									
Interactions and teleconnections		*					*												*
Climate Simulation and Prediction Models																			
Atmospheric models			*		*		*					*				*			*
Ocean models			*			*									*	*		*	
Coupled models			*			*									*	*		*	
Parameterized models			*		*	*										*			*
Test and evaluate models		*	*													*	*		*
Climate system sensitivity studies			*									*				*		*	*
Simulate annual cycle		*														*		*	
Climate predictability		*														*			
Statistical prediction techniques		*																	
Dynamical prediction		*														*			
Studies of Physical Climate Process																			
Ocean heat storage					*	*									*				
Geochemical cycles			*			*						*			*				*
Dynamic feedback mechanisms			*		*	*		*				*							*
Earth's radiation budget					*	*						*							*
DATA, INFORMATION, AND SERVICES																			
Observations																			
Atmospheric structure	*				*			*											*
Oceans						*									*				
Precipitation and hydrology	*	*						*					*	*					
Snow and ice					*										*			*	
Radiation and composition			*		*						*	*							*
Data Management																			
Data set preparation	*	*		*	*		*	*		*	*		*	*	*		*	*	*
Data management systems	*									*				*		*			
Analysis and Projection																			
Current information and analysis		*		*			*		*	*	*		*	*					*
Forecasts		*		*						*	*			*					
Diagnose climate anomalies		*					*					*						*	*
Forecast improvement		*								*				*		*			
Information Services																			
Evaluate needs and services	*									*	*		*	*					
Develop new information products	*	*					*	*		*	*			*					
Deliver information	*							*		*	*								
Evaluate benefits	*	*								*	*			*					

For example, the problem of the relation of CO_2 to climate has been identified as a major priority today. But the Principal Thrust on CO_2 and Climate involves activity elements of Climate System Research and of Data, Information, and Services as well as of Climate Impact Assessment. Similarly, observations, part of the Data, Information, and Services component, are essential to the Principal Thrusts aimed at understanding climate.

Table 5 integrates the activities involved in the Principal Thrusts and Areas of Program Concern with the elements of the Program components. The vertical margin identifies the components of the Program. The horizontal margin identifies the Program's priority efforts.

Asterisks in the body of the table identify the specific activities that contribute in a major way to these priority efforts, or activities that the priority efforts affect. For example, information on and analyses of current climate, a supporting activity within Data, Information, and Services, is a necessary ingredient to the Principal Thrusts in Climate Prediction and in Climate and World Food Production. Asterisks appear in those boxes. Similarly any progress in global precipitation measurements, an Area of Program Concern, would contribute significantly to current analyses of climate, thus an asterisk is in that box. This chart illustrates both the breadth of activities that contribute to the various priority efforts and the range of Program efforts needed to support a program.

The National Climate Program Act requires periodic revision and extension of the National Program. As priorities change, new initiatives will be proposed and others modified or eliminated. The components of the continuing activities will provide an internal structure for the Program as priorities change. Thus all present and future priority efforts depend on continuing activities. Continuing activities can generate new priorities for the future.

Finally, areas that are not given high priorities in this Plan could become continuing activities in a revised Program. For example, acid rain is an atmospheric phenomenon that apparently has no physical interaction with the climate system. However, it is the result of human activities, and it may be compared and contrasted with human interventions, such as heat islands, deforestation, and production of CO_2 from fossil fuels, that do affect climate processes.

On the basis of present knowledge, it is not appropriate to include acid rain as a major initiative of the first National Climate Program Plan. However, continuing climate research and impact assessment could identify interactions between acid rain and the climate system, and could raise national and international policy issues related to acid rain and climate. Thus acid rain could become a priority concern of future National Climate Program Plans.

In August 1979, President Carter mandated the development of an interagency acid rain assessment plan, with the Council on Environmental Quality (CEQ) working with EPA and USDA. Several Federal agencies, some States, and several industrial groups have begun acid rain research programs, and the United States and Canadian governments are cooperating in efforts to deal with this problem.

PART II

THE CLIMATE PLAN

CHAPTER III

PROVIDING CLIMATE PRODUCTS

The Climate Program must provide prompt and useful information.

Principal Thrust	Lead Agency
Generation and Dissemination of Climate Information	NOAA
Climate Prediction	NOAA

Area of Program Concern	Participating Agencies
Global Precipitation Measurements	NOAA/ NASA/ DOD
Surface Climate Data Networks	NOAA/ FAA/ DOD

A. Principal Thrusts

1. Generation and dissemination of climate information

Productive use of climate information by government at all levels and by the private sector must be increased. This can be done by establishing effective mechanisms to make climate data and information available to users.

Need

A major motivation for the establishment of the National Climate Program was to improve dissemination and use of climate information. The Congress found that "information regarding climate is not being fully disseminated or used." It mandated "management and active dissemination of climatological data, information and assessments" as a program element and provided for an intergovernmental program to help provide climate information to users. Advisory groups and individuals had told the Congress of the potential for making greater use of climate information. They had pointed out repeatedly that new economic benefits, increased productivity and reduction of the effects of climate-related hazards need not await breakthroughs in climate prediction. These advisers felt strongly that better dissemination alone would achieve significant results.

The Climate Research Board's 1979 Summer Workshop (Climate Research Board, 1979a) reaffirmed the importance of this program element, pointing to the fields of energy, agriculture, transportation, and environmental regulations as areas where intelligent use of climate information has paid off. This Principal Thrust is premised on the conclusion of the Board that there are many similar opportunities in which the benefits are not realized fully. The National Climate Program will identify these opportunities and facilitate the beneficial use of climate information.

There are growing needs for applying of climate information. For example, DOE recently proposed regulations on energy performance standards for new buildings that will require greater use of climate information by architects and builders.

Local and State governments and Federal agencies need an effective system for using climate information to meet public service responsibilities. DOD has a climate information system that can serve as an example for the civil sector. Major commands have staff weather officers and staff meteorologists who recognize needs for climatological assistance and help respond to them. The applied climatologists stationed at the U.S. Air Force Environmental Technical Applications Center (USAFETAC) and the Navy Fleet Numerical Oceanography Center, or attached to other national centers where climate information is available, produce the data summaries or perform the necessary studies. The information is then interpreted for the user by the staff weather officer (or equivalent). According to USAFETAC, benefit-to-cost ratios for these services are better than 10:1. This type of effort could be extended to the civilian sector to serve the public, local and State governments, and Federal agencies.

National and local data collections already exist. Many States have State climatologists who are familiar with local data sources, understand information needs, and can apply the data and information competently. Also, private professional climatologists interpret climate data and information. An effective national system for generating, disseminating, and using climate information will take full advantage of these capabilities and will establish clearly the roles of the national centers, the State climate programs, and the private climatologists in the overall system.

Lead agency

NOAA will lead this Principal Thrust. NOAA's National Climatic Center will do much of the work, because of its present data management and information service functions and its cooperative relations with State climatologists. Departments with extension or advisory services in climate-related areas (USDA, DOE, DOI, and DOC) will also be involved. The National Climate Program Office will aid in the initial stages of this Thrust, developing and evaluating options and guidelines for involvement of the State programs.

National program

The National Program will provide the means to:

- Identify potential uses and users of climate information.

- Extract from climate data the information that is appropriate to particular uses.
- Assure that the data collection networks and the basic data sets are adequate to meet users' requirements for data and information.
- Disseminate information and deliver services matched to location and needs of the users.

This effort will have two complementary structures: one for Federal functions and Federal activities, and the other for State activities and the Intergovernmental Climate Program. Both structures depend on private climatologists to tailor climate information to individual users' specific needs. Thus, an objective of the National Program is to help consultants provide more effective services to users.

The Federal structure is already functioning and beginning to operate more effectively. The intergovernmental structure has not been formally established, although individual State programs have improved in response to demands from users and the enactment of the National Climate Program Act.

Federal Structure. The Federal functions include:

- Establishing a coordinated national climate data inventory and clearinghouse.
- Improving access to data from national networks.
- Enhancing efforts to communicate with users and respond to their needs.

At its 1979 Summer Workshop, the Climate Research Board gave high priority to the clearinghouse function. It involves cataloging and periodically updating an inventory of climate data and information holdings, and establishing a system for referring users to data and information sources. Three aspects of the data information problem will receive attention: (1) improving the availability, utility, and accessibility of existing data and information; (2) developing and implementing a long-range plan for a national climate information system; and (3) cooperating with the World Meteorological Organization (WMO) to develop an international climate information system.

As the inventory is developed, topical and regional information catalogs will be published and special catalogs will be designed to acquaint the general public with availability of data and information relating to factors such as health, energy, architecture, travel or relocation, and natural hazards.

Access to data collected from national networks requires identifying sets of data in high demand and processing these sets to permit quick, easy, and inexpensive access. The process includes distributing subsets of these data to local offices, as justified by demand; providing convenient access for users; and keeping the data sets current.

Federal efforts to establish contacts with users must be limited to major user groups concerned with national issues. Contact with individual users is a local function. Federal activities in this area will include continuing a series of user workshops (for architects, builders, engineers, public health officers, consulting climatologists, agriculturists, etc.) designed to identify each group's specific needs, and systematically evaluating users' recommendations. Additional workshops will outline programs for meeting user requirements. A team of outside experts comprising users, managers, and producers of climate information will be assembled to assure that user views are considered in the design and operation of the climate data and information system.

Intergovernmental Structure. The role of State programs must be examined, clearly defined, and strengthened. An initial effort being pursued, in cooperation with the American Association of State Climatologists, is to design minimal communication/computational facilities required for data and information to flow among States and national centers. Additional studies will explore the States' roles in data collection and assembly, including a possible State role in maintaining the cooperative observing program now managed by the National Weather Service. A few pilot projects, designed to test ideas for providing climate services and evaluate their benefits, will be funded in Fiscal Years 1980-82. These pilot projects will seek to demonstrate the importance of local and regional user-oriented climate studies and services, leading to decisions by Federal and State governments as to what activities should be supported and by whom.

Milestones

Milestones for this Thrust, presented below, do not assume increased budget authority for the National Climatic Center during FY 1980-84. Additional funds (about $200,000) for the National Climate Program Office (NCPO) will be used in FY 1981 to explore aspects of the Intergovernmental Program.

FY 1980

- Form team of outside experts.
- Consolidate and evaluate recommendations from past user workshops.
- Determine priorities for data set preparation.
- Complete national survey of Federal, State and nongovernmental climate information systems.
- Initiate demonstration studies for roles of State programs.
- Hold additional user workshops to identify data and information needs.

FY 1981

- Publish first climate information inventory, a guide to workshops, inventories, and information services.
- Hold new user outreach workshops based on documented uses and benefits of climate data and information.
- Complete processing of selected high-priority data sets.
- Complete feasibility study of automated transfer of information among national data centers.

- Initiate development of climate information exchange interfaces between the Federal system and State/regional/local systems.

FY 1982

- Initiate serial publication of topical and regional data catalogs (inventory supplements).
- Establish guidelines for State participation in local aquisition and processing of local climate data.
- Complete design of long-term national climate data/information system.
- Sponsor, with the World Meteorological Organization, a planning conference on climate data inventories and information systems.

FY 1983

- Begin implementation of climate information interfaces with State and regional systems.
- Initiate international climate information and inventory system development project.

Options for future program development

(See also discussion of options in Chapter I.)

The Intergovernmental Climate Program. The National Climate Program Act mandates that mechanisms be established for "intergovernmental climate-related studies and services" and that a "program for Federal and State cooperative activities " be established. Chapter VII describes the Intergovernmental Climate Program component. The main function will be the generation and dissemination of climate information. Implementation will be phased. An exploratory program of selected projects (Phase I) will commence in Fiscal Year 1980. On the basis of these activities, decisions will be made as to divisions of responsibility and funding among Federal, State and private agencies and institutions. Many recommendations have been made for additional functions to be carried out in such a program; the most recent ones came from the Climate Research Board's 1979 Summer Workshop. These recommendations will be examined carefully during the exploratory program.

A multiyear cumulative expenditure of $1 to $2 million spread over a variety of activities should suffice to attain the goals of these Phase I activities and define future programs.

Federal climate information and data functions include a second option for future program development. Because of increasing interest in climate, deficiencies in climate data and information management are being identified more rapidly than they can be remedied. Files in the National Climatic Center alone contain nearly 2 billion observations. Before useful data sets can be generated from these sets of basic observations, the data must be checked for quality and completeness and placed in compact form in an automated data base. This process is proceeding slowly, but it could be accelerated with additional funding. It would take about $8M and 3 to 5 years to process completely the historic data sets. The data management system must also provide timely and efficient processing of large volumes of satellite data.

The basic data sets must also be converted into summaries and tailored to specific user needs. Workshops involving users have been identifying particular kinds of summaries and statistical tabulations that are needed for applications such as designing buildings for energy conservation.

There is a growing demand for these tailored information products, and the cost of providing them would be about $0.5M to $2M per year.

2. Climate prediction

Improved accuracy and earlier predictions of climate variations for periods of months and seasons must be provided.

Need

The National Climate Program Act specifies, as an element of the National Climate Program, the development of "methods for improving climate forecasts on a monthly, seasonal, yearly, and longer basis." The emphasis of this Thrust will be on improvement of relatively short-term climate projections (up to a year or two) where the opportunities for achieving useful, timely results appear to be greatest.

Many economic, social, and political activities are affected by short-term climate fluctuations. Some knowledge of the probable severity of the forthcoming winter, based on knowledge of the physical behavior of the climate system, is clearly more valuable for planning reserves of heating oil than simple estimates of the likelihood of a severe winter based on historical considerations. Planning for this kind of activity requires both a clear understanding of the effects of climate fluctuations on a particular activity and some indication of the climatic conditions to be expected. Standard climatic probabilities (i.e., those based purely on the statistics of a substantial record of the past climate) can serve as useful statements of climate expectations. They include information on the average or "normal" occurrences, on the variability from one period to another, and on what constitutes an "unusual" event. They do not, however, provide information that distinguishes the forthcoming period from any other. The essence of climate prediction is to provide reliable statements about the probabilities of future climate that distinguish the period in question from other comparable periods. With the present state of the art, monthly and seasonal outlooks issued by NOAA's Climate Analysis Center have probabilities of being correct of 55 to 65 percent, depending on the time of year and whether precipitation or temperature is the element in question. The standard probabilities of "above normal" or "below normal" conditions are by definition 50 percent.

Modest gains in the precision of predictive probabilities, the development of a capability to state them farther in advance, or the expansion of their scope to clusters of seasons over several years would benefit greatly many planners facing climate-related problems. Requests for improved climate predictions have been made by several government agencies, specifically DOE, DOI, USDA, and the Army Corps of Engineers, who must deal with climate-related

problems in areas of energy, food, and water resources. Many businesses (e.g., utilities, agribusiness, outdoor recreation, merchandising) and State and local governments have also demonstrated their interest in climate predictions by subscribing to private forecast services or the Climate Analysis Center outlooks.

Advances in computer technology encourage expectations for progress in climate prediction. The capability is emerging to perform the complex, time-consuming calculations needed to learn whether numerical models and statistical techniques can lead to better and earlier forecasts. Improved global observations, especially during and since the Global Weather Experiment, support more comprehensive diagnostic studies and numerical experimentation. On the basis of theoretical and analytical studies of short-term climate variations, insights are evolving that will help distinguish variations that are predictable from variations that will remain unpredictable.

Lead Agency

NOAA will lead the planning and implementation for this Principal Thrust. NOAA's Climate Analysis Center will remain the focus for operational predictions and for improvements in operational products. NOAA will also support, through NCPO, experimental prediction by non-Federal groups. Other agencies such as the Air Force, NASA, NSF, DOE and USDA will participate actively.

Plan of action

Improving climatic predictions will involve research in prediction methods, in the diagnosis of climate variations, and in improved methods for the verification of climate predictions. The program will include the development of prediction formats and terms that are more informative for the users. The program plan for Climate Prediction is established to attain, within 5 years, the following results:

- Seasonal outlooks issued up to several months before the season begins, having skill similar to those now issued 1 day before the season begins.
- Improvement of outlooks for forthcoming months and seasons through greater accuracy, variety of elements predicted, and better information content (e.g., more specific statements of probability, greater spatial resolution, and specification of risks of extreme events).
- Continuous monitoring of the current state of global and regional climate in terms and formats useful to those involved in gaging impacts.

Specific elements of the plan for climate prediction are:

- The Climate Analysis Center (NOAA/NWS) will continue to design and operate the civil system of climate predictions and monitor current climate fluctuations. The Center will maintain cognizance of international and national prediction research and development and identify promising new approaches for operational testing and evaluation. The Climate Analysis Center (CAC) will also make and support new diagnostic studies, new statistical forecasting techniques, and comparative testing of predictions, and will solicit advice on user needs.
- Experimental Forecast Groups will be established, when it is deemed appropriate, at non-Federal research institutions or universities to develop and test a variety of innovative experimental forecast techniques and to develop appropriate verification methodologies. (Further discussion of the Experimental Forecast Groups can be found in Chapter VII, where special aspects of the Climate Program are discussed.)
- The USAF Environmental Technical Applications Center (USAFETAC) will maintain a climate awareness and assessment capability designed to serve national defense requirements. ETAC and CAC will share all products and analyses not peculiar to military requirements.
- Federal laboratories active in climate modeling, in particular the NOAA Geophysical Fluid Dynamics Laboratory and the NASA Goddard Laboratory for Atmospheric Sciences, will continue their programs in the modeling aspects of forecast development and testing.
- NSF will support diagnostic and forecast development research in response to proposals from universities, and through studies conducted by the National Center for Atmospheric Research (NCAR).
- DOE and USDA will analyze predictive capabilities in terms of specific requirements and may support research on the prediction of climatic elements having particular relevance to their agency responsibilities.
- The NOAA Environmental Research Laboratories (ERL) will support diagnostic climate investigations as part of other on-going climate research activities as, for example, in the Equatorial Pacific Ocean Climate Studies (EPOCS) and Geophysical Monitoring for Climate Change (GMCC) programs.
- The Intergovernmental Climate Program, when established, will provide advice to the CAC and the Experimental Climate Forecast Groups on particular parameters or formats conducive to more useful predictions.

Milestones

The following specific milestones are to be accomplished within the scope of currently approved funding. They are based on resources of $2.1 million per year available to CAC for prediction research and services, $0.1 million for an Experimental Climate Forecast Group in FY 1980, and about $0.2 million per year thereafter. Congressional approval of the FY 1981 budget is assumed.

FY 1980

- Complete an evaluation of the state of the art in climate prediction, and establish priorities for research and development.
- Initiate research and development, through CAC, to improve and extend the lead time of monthly and seasonal outlooks.
- Establish the first (non-Federal) Experimental Climate Forecast Group to investigate and develop improved climate prediction methods.
- Determine specific diagnostic data base requirements, select appropriate climate indices, and initiate in CAC the data acquisition and processing procedures needed to support prediction research and services.
- Increase the frequency at which seasonal temperature outlooks are issued, from 4 per year to 12 per year.

FY 1981

- Begin routine monitoring, through CAC, of parameters of global climate.
- Initiate a "User Conference Series" to determine specific prediction needs in application areas such as agriculture, energy, water resources, and transportation.
- Recast seasonal and monthly outlooks in more detailed probabilistic terms.

FY 1982

- Test middle-latitude, objective predictions based on new types of external predictors.
- Based on predictability studies, evaluate opportunity for extending the lead time of seasonal outlooks.
- Initiate distribution of a "World Climate Bulletin" containing recent and current climate indices and global climate analyses for use by those engaged in impact assessment, experimental or operational prediction, and diagnostic studies.
- Adapt satellite methods for monitoring ocean and land surface processes.

FY 1983

- Evaluate the first series of forecasts produced by an Experimental Climate Forecast Group.
- Apply improved objective prediction methods to operational predictions for North America.
- Experiment with objective middle-latitude predictions for longer lead times.

FY 1984

- Begin operational, extended lead time predictions for North America.
- Participate in international evaluation of progress on prediction techniques development.

Options for future program development

(See also discussion of options in Chapter I.)

Progress in climate prediction for the next 3 to 10 years will depend on the results of research efforts by the Experimental Climate Forecast Group(s) and the Climate Analysis Center and results of research supported by NSF and other agencies. Increasing the number of new prediction concepts that can be tried, and the rate at which they can be properly formulated, tested, and evaluated, will require broadening the base of participation in experimental prediction to a larger number of qualified scientists. Progress will also depend on the rate at which the Climate Analysis Center is able to make meaningful operational evaluations and generate the analyses and indices that support further innovation.

Climate Prediction activities under consideration include:

- Establish, as deemed appropriate and useful, an additional Experimental Climate Forecast Group or two to investigate, develop, and test new climate prediction methods.
- Introduce CAC issuance of "climate alerts and watches" on an irregular basis, as conditions warrant.
- Explore use of global circulation indices in determining variability and risks of extreme events.
- Extend new prediction methods to cover the Northern Hemisphere and the Tropics.
- Test feasibility of variable-length "regime" predictions.
- Test applicability of atmospheric numerical models to prediction (and/or other operational suggestions emerging from Experimental Climate Forecast Groups).

Each experimental climate forecast group is estimated to require $200K to $500K, depending on the scope and nature of its activities and staff.

CAC, with added staff to carry out additional operational functions and support necessary and appropriate applied research, could require about twice its present resources in several years.

B. Areas of Program Concern

1. Global precipitation measurements

Precipitation and temperature are the two climate elements that affect human activities and the environment most directly. Reliable, timely estimates of precipitation for the major agricultural regions would greatly improve our ability to estimate crop yields and food production. Precipitation is accompanied by the release of latent heat of condensation and is thus a significant factor in atmospheric energetics. It is, however, highly variable in both space and time and therefore difficult to measure.

Over many of the more heavily populated areas of the Earth, ground-based measurements are adequate for most purposes. Over oceanic areas, present observations are

totally inadequate for diagnostic and research purposes For large continental areas, precipitation measurements are marginal at best, and are not even sufficient to meet local needs for hydrologic information.

The need for global measurements suggests the use of satellites. Satellites can be platforms for remotely sensing precipitation and for communicating observations from *in situ* sensors. These uses are now being explored, but there remain significant practical problems in developing an adequate and comprehensive measurement system.

Research groups at NOAA, both from the Environmental Research Laboratories and the National Environmental Satellite Service, NASA, Colorado State University and the University of Hawaii have made considerable progress in developing special techniques for estimating precipitation from routinely available satellite data. However, the approaches require the processing of large amounts of data to produce estimates that may be valid only over limited areas. These techniques alone will probably not solve the requirement for global applications.

Research and development have been done on satellite remote sensing specifically designed to measure precipitation. Both active (radar) and passive (microwave) sensors are being considered; however, no specific solution is in sight. The problem is exacerbated by the great variability of precipitation, its systematic dependence on time of day, and physical limitations on satellite orbits.

The National Climate Program must deal with both long-term solutions and near-term remedies. Technique developments aimed at operational products, including the interpretation of surface reports and satellite observations, are being emphasized.

Action

- Coordinate planning of technique development to integrate more effectively the diverse efforts now being pursued.
- Establish high-quality ground truth measurement networks in various climatic regions of interest.
- Coordinate satellite data management plans and activities, data requirements, and emerging precipitation-measuring techniques, so that suitable data products can be obtained from current and future operational satellites.
- Continue research and development of new satellite remote-sensing techniques.

These are mostly continuing functions, but more attention to coordination, collaboration, and integration is needed. The NOAA Climate Analysis Center, which is responsible for providing climate analyses and awareness information, will test and validate techniques, support relevant studies in the academic community, and interface data products with other components of the National Meteorological Center and the National Environmental Satellite Service. NASA will continue to investigate novel satellite techniques for precipitation measurements. It is premature, however, to predict the specific options for experimental satellite instruments that will develop or when they will be available for testing.

2. Surface climate data networks

Observations of weather variables provide basic data for farmers, engineers, merchants, planners, ecologists, climate researchers, and others. Some locations have uninterrupted, long-term surface weather measurements of high quality, but the networks established to collect the observations often do not have sufficient stability, or measure the proper parameters or observe with the proper frequencies to serve the host of climate applications. The Climate Research Board's 1979 Summer Workshop emphasized that "there are important data and information gaps relative to important needs in the fields of energy, food, production, environmental monitoring, water supply, and climate prediction."

The National Weather Service (NWS) and the Federal Aviation Administration (FAA) now operate principal surface networks. Both networks are justified largely by operational requirements (weather warnings and predictions, aviation operations).

NWS weather stations range from fully equipped observing sites, staffed around the clock, to cooperative stations where a volunteer observer measures only precipitation once a day. Cooperative observing stations represent the substantial majority of the total.

A significant component of the U.S. surface climate observing network consists of a small number of "benchmark" stations, established at locations and in institutional settings that tend to assure very long continuous records with minimal change in sensor sites or surroundings. The present network comprises 21 Reference Climatological Stations, supported jointly by EDIS and NWS, where observations are made of precipitation, air temperature, and wind speed and direction.

The NWS and FAA networks are supplemented by a large number of limited area networks operated by States and by other Federal agencies, and occasionally by private enterprise. Typically, such networks measure surface weather variables that are closely related to the sponsor's purpose. They vary widely in instrumentation and in observing, maintenance, and processing practices as well as in data quality, completeness, and accessibility.

An adequate surface observing network is absolutely essential for National Climate Program activities. Defining requirements adequate for all purposes is difficult, but the Climate Research Board (1979a) offered some specific recommendations:

"1. Assure the integrity of the NOAA cooperative climatological network and the quality of its observations . . . . This network has not received care and attention commensurate with its value as the source of data essential to many local applications in agriculture, site selection, construction, etc.

"2. Improve and expand the network of solar and terrestrial radiation measurements. The quality and quantity of existing records fall seriously short of what is needed in view of the emerging importance of solar radiation as an energy source, the importance of such radiation as a driving mechanism of climate, and as a complement to the Earth Radiation Budget Experiment.

"3. Assure the continuity of existing climatic benchmark reference stations and increase their number so as to provide an objective set of data against which to observe climatic change."

At present the National Climate Program is focusing on the maintenance of the existing surface network. NOAA will attempt to continue operating a 38-station solar radiation network originally established by DOE. Cooperative weather stations, particularly those at which temperature and precipitation have been measured for several decades, provide a valuable data base for analysis of local and subregional climatic conditions. Efforts will be made to retain all cooperative stations, even though they are no longer needed for operational weather purposes.

Action

- NCPO will commission a study to define the requirements for daily surface measurements.
- The role of State climate programs in the maintenance of the cooperative observing program will be explored.
- The possibility of State climate programs assuming responsibility for overseeing the supplementary observing programs will be examined, particularly with regard to their serving as a source of information on local data quality and availability. This examination will require NCPO to initiate exemplary surveys and evaluation studies in one or several States.

An important program option to be considered is the expansion of the Reference Climatological Station network. NOAA/EDIS studies indicate that a doubling of the existing network to about 40 "benchmark" stations within the conterminous United States, with solar radiation measurements added at all sites, would meet current and projected requirements. Implementing this option would cost about $0.25 million at most.

CHAPTER IV

RESPONDING TO IMPACTS AND POLICY IMPLICATIONS OF CLIMATE

The Climate Program must identify impacts on climate by man and impacts of climate on man. This information is needed in forming policies to handle such impacts.

Principal Thrust	Lead Agency
Carbon Dioxide, Environment, and Society	DOE
Climate and World Food Production	USDA
Area of Program Concern	**Participating Agencies**
Climate-Related Hazards	USDA/DOD/NSF/FEMA/DOI/NOAA
Energy Production, Distribution, and Demand	DOE/NOAA
Impact Assessment Methodologies	DOE/USDA/NOAA/EPA/NSF
Regional Climate Effects of Humans	DOE/EPA/USDA/NOAA/NSF
Semiarid and Arid Lands	DOI/USDA
Water Resources Management and Planning	USDA/DOD/DOI/EPA/DOC

A. Principal Thrusts

1. Carbon dioxide, environment, and society

The ability to predict the agricultural, environmental, and societal consequences, both national and international, of increasing atmospheric concentrations of carbon dioxide (CO_2) must be developed to permit informed policy decisions to be made on the use and development of energy and other resources. This goal necessarily implies identifying and evaluating the implications of a wide range of energy and resource policy options.

Need

Systematic observations begun more than 10 years ago have shown a steady increase in atmospheric CO_2 concentrations. A 1977 National Academy of Sciences report (Geophysics Research Board, 1977) concluded that "the climatic effects of carbon dioxide release may be the primary limiting factor on energy production from fossil fuels over the next few centuries." A more recent report by an Academy panel (Climate Research Board, 1979b) found "no reason to doubt that climate changes will result" if CO_2 continues to increase, "and no reason to believe that these changes will be negligible."

There is a consensus in the scientific community that carbon dioxide from the unrestrained combustion of fossil fuels is potentially the most profound environmental issue facing mankind. What society now chooses to do, or not to do, can profoundly affect the environment and society a few decades hence. Our energy strategy must be chosen with consideration of these effects—and with much care.

What is the rate at which atmospheric CO_2 concentrations are increasing and will increase in the future? Observations made at such diverse locations as the South Pole, Samoa, Hawaii, and Alaska demonstrate unequivocally that the increase is global. Over the last two decades the rate of increase has been getting larger, paralleling very closely the rate at which fossil fuels have been burned throughout the world.

About one-half of the CO_2 produced through combustion of fossil fuels seems to remain in the atmosphere. The remaining CO_2 must be taken up in the larger CO_2 reservoirs —the biosphere or the oceans. Some scientists believe that the biosphere has been a source and not a sink of CO_2. They contend that as forests are cleared and the soil tilled the biospheric storage of CO_2 is substantially reduced. As the wood and organic matter in the soil burn or decompose, CO_2 is then released to the atmosphere. The magnitude of this effect is not well known, and some doubt its significance.

The rate at which the oceans can act as a sink for the added CO_2 is also in doubt. The cold deep waters of the world oceans could easily absorb the CO_2 produced by burning fossil fuels, but the warmer upper layers of the oceans are nearly saturated with CO_2 and are very nearly in equilibrium with the atmosphere. For the oceans to take up excess CO_2 there must be mixing downward to the deep waters from the warmer upper layer, and most ocean circulation models indicate that this is a very slow process.

We must analyze the entire global carbon cycle to project how rapidly atmospheric CO_2 concentrations will continue to increase. Almost all models suggest that some time in the 21st century, atmospheric CO_2 will be double its preindustrial value. Some suggest that this will occur early in the century (say, 2030), and some say later (say, 2060).

How will increased CO_2 alter climate? CO_2 is a gas that absorbs and reradiates infrared radiation. Along with other such gases, the most important being water vapor and

ozone, it plays a very significant role in maintaining the present climate. Calculations of the direct net heating—the "greenhouse" effect—resulting from doubling CO_2 and altering nothing else imply a warming of surface temperatures by 1° C. But it is impossible to double CO_2 and alter nothing else. Warmer surface temperatures would tend to increase the water vapor content of the atmosphere, which would about double the warming effect of the CO_2. Other possible alterations resulting from CO_2 increases—"feedback" mechanisms—include changes in the radiative effects of clouds, snow, and ice, and the circulation and transport of heat and momentum by the oceans and the atmosphere.

The NAS Panel (Climate Research Board, 1979b) examined in some detail numerous models incorporating various feedback mechanisms. Their report states:

> "We conclude that the predictions of CO_2-induced climate changes made with the various models examined are basically consistent and mutually supporting. The differences in model results are relatively small and may be accounted for by differences in model characteristics and simplifying assumptions . . . . If the CO_2 concentration of the atmosphere is indeed doubled and remains . . . long enough . . . our best estimate is that changes in global temperature of the order of 3° C will occur and that these will be accompanied by significant changes in regional climatic patterns."

More analysis is needed of the nature and magnitude of these changes in regional climatic patterns. Regional temperature and precipitation characteristics—their means, seasonal patterns, and year-to-year variability—are likely to be more severely affected than global mean temperature. Models are now able to give only a few tentative indications of the regional climatic effects of future increases in CO_2. Although the models generally agree that warming will be more pronounced at high latitudes than at low ones, regional effects are more complicated and varied than a simple variation with latitude. The models indicate that precipitation patterns will be affected, but their representations of oceans and other physiographic features are too crude to permit much reliance on their results.

How will the increase in CO_2 affect the rest of the environment, either directly or together with climate changes? In this context, the environment includes natural terrestrial and marine ecosystems. It also includes the managed biosphere—agricultural and grazing lands and forests—the cryosphere, and ocean circulations.

Little overview of the environmental consequences of increasing CO_2 is available. Some analyses have been made of effects in particular areas, such as agriculture, ecology, and oceanography, but these analyses have never been integrated across disciplines or related in a comprehensive overview.

A recent workshop held by the American Association for the Advancement of Science for DOE was perhaps the first interdisciplinary gathering to address these issues. Some of the concerns that were identified included:

- Ocean phenomena—How would ocean circulation or biogeochemical changes in turn affect the formation of bottom and intermediate waters?
- Cryospheric behavior—Would warmer ocean and air temperatures tend to dislodge a huge Antarctic ice sheet, causing a cataclysmic rise in sea level?
- Effects on the unmanaged terrestrial biosphere—How would species and ecological systems respond to high levels of CO_2 and altered climate?
- The managed biosphere—What might be done to improve the adaptability of the agricultural system?

What will be the social and economic consequences of increased CO_2? It is not sufficient to consider only net effects. Who is affected, and when, may be overriding issues. This is an extremely difficult question and would be so even if the direct physical and biological effects could be delineated. A major source of that difficulty is the need to assess what the Nation's and world's social and economic situation will be 50 or 100 years hence.

What are the options available to ameliorate the unwanted effects and impacts? Possible alternative actions include minimizing the buildup of atmospheric CO_2 and minimizing undesired effects by adapting to their consequences. These options must be identified and their implications evaluated in the light of all the climatological, environmental, economic and other relevant information available. It is not now evident that any major actions are warranted.

Lead Agency

Leadership responsibility for this Principal Thrust is assigned to DOE, which has, in effect, been carrying out that leadership responsibility since 1977 by establishing advisory bodies, organizing planning teams and workshops, and supporting relevant research.

To support DOE, the National Climate Program Office has established, under authority of Section 5 (e)(2) of the National Climate Program Act, an Interagency Committee for CO_2, Environment, and Society. This committee, chaired by the Manager of the DOE CO_2 Research and Assessment Program, will serve as a formal body for coordinating the CO_2 efforts of the various Federal agencies. One of the major functions of this committee will be to facilitate multiagency participation in the planning as well as in the research.

Several agencies, all represented on the Interagency Committee, will be directing their own research activities, often supported by pass-through funds from DOE. DOE will receive their reports and information and be responsible for comprehensive evaluation and planning.

Planning for international activities, especially those that involve multinational organizations and institutions,

will be carried out through the National Climate Program Office to assure consistency with other international climate activities. Those closely involved with the CO_2 Program will, of course, suggest initiatives and participate in international planning activities.

National Program

Several guidelines have been established that serve to define the strategy for the National Program on Carbon Dioxide, Environment, and Society:

- The CO_2 question is fundamentally an international issue. The climate context is global, and the policy options must be globally conceived. National policy on CO_2 emissions, in itself, must necessarily fall far short of confronting the global issue. Therefore, the National Program will strive to maximize international cooperation in relevant climate, environmental, and policy research; data gathering and analysis; and information dissemination and assessment.
- The Program must be comprehensive and interdisciplinary. The traditional bounds of climate research, economic research, environmental research must be transcended to allow policy issues to be addressed in all their aspects. Cooperation among disciplines—especially between the physical and social sciences—must be fostered throughout the planning and execution phases of the Program.
- Several areas of research relevant to CO_2 and Climate are already very active. The Program will supplement these activities only as necessary to ensure their adequacy, while exercising leadership to support promising new activities in less developed fields.
- Review, integration, and evaluation of progress and the identification of policy options and their consequences must be part of the total program effort.
- The CO_2 and Climate effort must involve extensive collaboration among agencies and between Federal and non-Federal organizations, but with a single focus for planning and leadership.

DOE has prepared a detailed plan on CO_2 research and assessment entitled "A Comprehensive Plan for Carbon Dioxide Effects Research and Assessment, Part I." The plan is the outgrowth of an extensive process that has involved a large number of scientists, including many from abroad.

The plan is complete with regard to research on the global carbon cycle and the effects of increasing carbon dioxide on climate, and a first revision is being prepared. Part II of the plan, dealing with the effects of a CO_2 increase and climate system change on other parts of the environment and on society, is being developed. Definition of the review, integration, and evaluation (assessment) program has begun, but is not yet documented. The program planning related to amelioration and adaptive strategies has not yet begun in a formal sense. There will be concentrated efforts in 1980 to complete the planning regarding environmental and societal effects, allowing major programmatic activities to be initiated in FY 1981.

Table 6 gives the outline of the comprehensive research program. This table indicates the five major research categories, one corresponding to each of the significant aspects of the Principal Thrust, plus a sixth category for the very important assessment function. An unpublished 1979 Department of Energy working document entitled "Research Issues" contains more detailed statements of program content and priority for various issues and subcategories and summaries of relevant research projects supported by various agencies.

Milestones

Significant milestones for this thrust draw upon the more complete list in DOE working documents. The milestones depend upon continuing programmatic efforts in several agencies, but DOE will support most of the incremental effort. Many, but not all, of the milestones listed here refer to DOE activities. This will change as the roles of other agencies become more explicit and comprehensive.

FY 1980

- Begin feasibility study of remote sensing of global biomass.
- Make operational the NOAA/DOE worldwide network for monitoring CO_2.
- Begin major investigation of ocean mixing in the North Atlantic (Transient Tracers in Oceans Program, jointly supported by NSF and DOE).
- Hold workshop on CO_2 and the West Antarctic ice sheet.
- Complete observational phase of equatorial Pacific CO_2 Program (FGGE).
- Begin climate model studies with coupled ocean/atmosphere models.
- Begin assessment program.
- Publish draft program plan for research on the environmental and societal consequences of CO_2 increases and climate change (Research Categories III and IV).

FY 1981

- Make biomass measurement field test in tropical forest.
- Begin feasibility studies to estimate total ocean/organic carbon pool.
- Initiate CO_2 ecosystem fertilization studies.
- Begin funding research on the environmental effects of CO_2 increase and climate change on the managed and unmanaged biosphere.
- Begin funding research on social, political, and economic costs and/or benefits of global environmental change.
- Publish plans for research on amelioration and adaptation (Research Category V).

Table 6.—A National Program on carbon dioxide, environment, and society

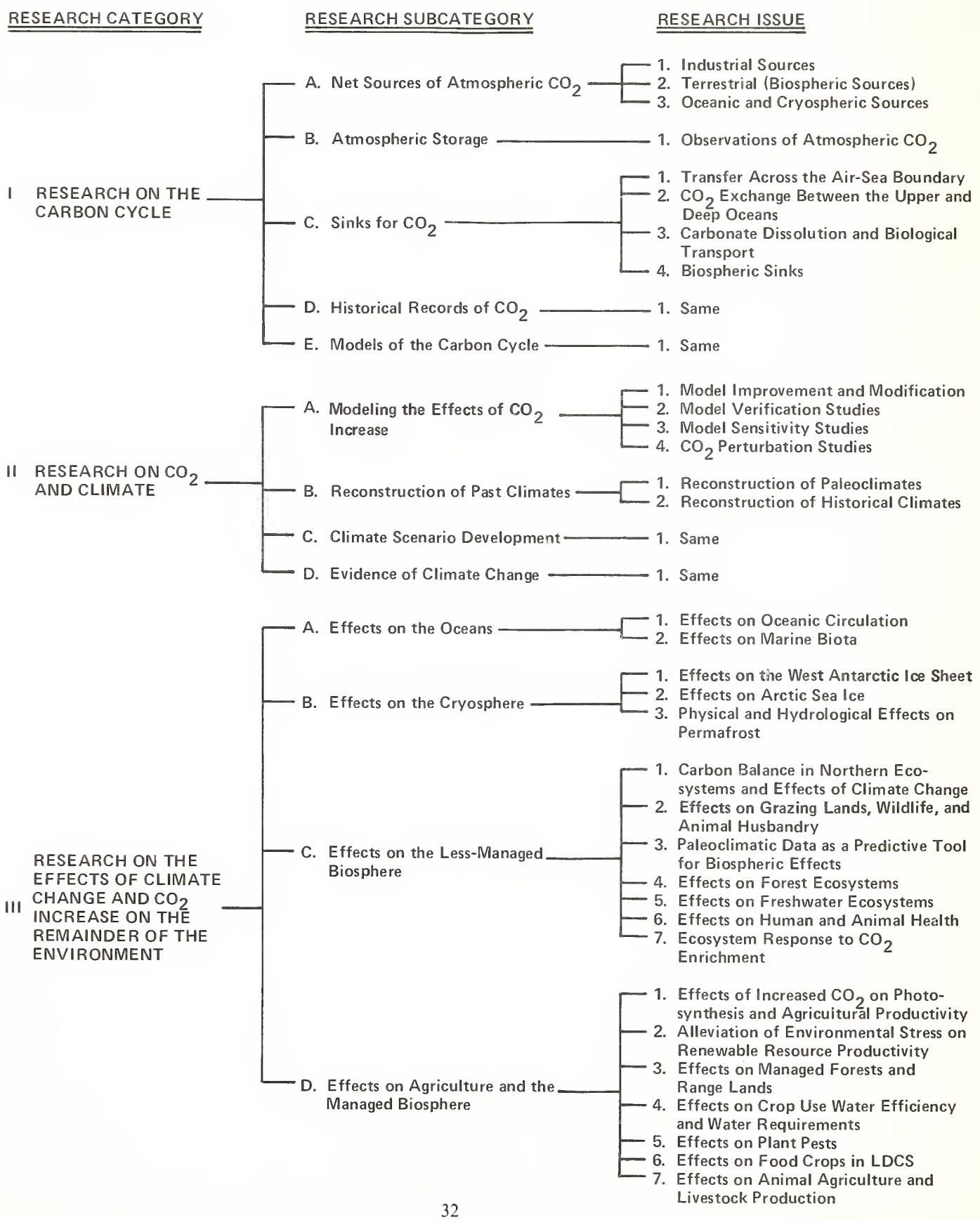

Table 6.—A National Program on carbon dioxide, environment, and society (con.)

RESEARCH CATEGORY	RESEARCH SUBCATEGORY	RESEARCH ISSUE
IV RESEARCH ON SOCIAL, POLITICAL, AND ECONOMIC COSTS AND/OR BENEFITS OF GLOBAL ENVIRONMENTAL CHANGE	A. Social and Institutional Responses	1. Cultural Determinants of Perceptions of Climate Change and Social System Reactions
		2. Climate Change, International Law, and Institutions
		3. Factors Affecting Vulnerability of Society to Environmental Change
		4. Political and Institutional Decision-Making in Response to Climate Change
		5. Perceptions of and Reactions to Environmental Change in Relation to Decision-Making
		6. Historical Dimensions of Effects of Climate on Human Societies
	B. Economic and Geopolitical Consequences	1. Economic Policy Evaluations of CO_2 Abatement
		2. Assessment and Resolution of Climate-Induced Strains on the International Economic System
		3. Mitigating Losses From Disruptions Caused by Environmental Change
		4. Planning for Environmental Change: Scenario Construction and Evaluation
V RESEARCH ON THE AMELIORATION OF GLOBAL AND SECTORAL IMPACTS	A. Preventative Measures	1. Same
	B. Curative Measures	1. Same
	C. Moderating Measures	1. Same
	D. Adaptive Measures	1. Same
VI REVIEW, INTEGRATION, AND EVALUATION (ASSESSMENT)	A. The 1984 Review, Integration, & Evaluation (Assessment) Report	1. Same
	B. CO_2 Information and Data System	1. Same

FY 1982

- Complete feasibility test of remote methods for biomass measurement.
- Complete North Atlantic cruises and measurements of the Transient Tracers in the Ocean program.
- Make preliminary estimates of climate sensitivity available from coupled ocean/atmosphere general circulation models.
- Sponsor an international meeting on carbon dioxide, environment, and society with sections on research, assessment, policy development, and public outreach.

FY 1983

- Publish summary results for all program elements for use in 1984 program assessment.
- Publish report on future climate scenarios.
- Make systematic estimates of CO_2 climate effects, including regional and seasonal aspects, available from model calculations.
- Publish semiquantitative models of environmental system response to a climate system change and CO_2 increase.
- Publish documents dealing with strategy and policy options.

FY 1984

- Conduct major interim program assessment. Begin redirection, termination, and/or initiation of research on basis of assessment.

Options for future program development

(See also discussion of options in Chapter I.)

DOE's plan for CO_2 research and assessment is divided into six categories (table 6):

- Carbon Cycle.
- CO_2 and Climate (modeling, reconstruction of past climates, evidence of change).
- Effect of Climate Change and CO_2 Increases in the Environment (oceans, cryosphere, biosphere).
- Social, Political, and Economic Costs and/or Benefits of Global Environment Change.
- Amelioration of Global and Sectoral Impacts.
- Assessment.

Planning is well advanced and research well underway on the first two categories—carbon cycle and CO_2 and climate. The degree of implementation of the other research categories depends on future funding decisions. Funding of Research Categories III and IV (environmental and social, political and economic effects) will be possible in FY 1981 for the most important environmental and societal consequences of increasing CO_2 in time for the 1984 Review. The DOE CO_2 Program will spend about $10.8 million in FY 1981.

A vigorous effort will be required to predict the environmental and societal consequences of increased CO_2 in the context of alternate energy strategies and economic and political scenarios. Additional resources are necessary for planned studies in biogeochemical cycles to predict how the CO_2 will be divided among the various reservoirs (oceans, cryosphere, biosphere, atmosphere). Detailed estimates will be prepared as more specific research plans are developed and the people and institutions to carry out the work are identified. These additional activities may require annual funding up to $10 million.

2. Climate and world food production

Assessments of weather and climate impacts on national and world food production are needed to develop strategies to deal with variable world food supplies.

Need

The major causes of season-to-season variation in world food production are climate fluctuations and weather extremes. One region may have poor production conditions, while others enjoy abundant food production. Information about climate effects on world food production is needed to develop plans and make tactical decisions to stabilize world food stocks and supplies. The importance of achieving this stability increases each year as populations continue to increase, levels of food intake increase, and the costs of production rise.

The national and international interests of the United States require that the impact of climate on domestic and world food supplies be understood better and that this knowledge be used in developing rational approaches for managing global food supplies. Such approaches would involve the U.S. government, farms, agribusiness concerns and the fishing industry, and international agencies concerned with production, distribution, and use of world food supplies.

Research on the impacts of climate on crop production has been carried out for many years, mostly on experimental plots. Less has been done to identify and measure impacts on fisheries and livestock. Experience is limited in using climate information to help shape food policies. The proposed program will build on present capabilities to measure and apply information about the effects of climate on food production, and will augment these capabilities to use climate information more effectively in food policy decision making.

Concern about the effect of climate fluctuations on world food supplies has been expressed at several international conferences on food and climate. The United Nations Food and Agriculture Organization (FAO) has in recent years increased its efforts to monitor and report on world food production and climate conditions affecting production.

The World Climate Program, being planned by WMO in cooperation with the International Council of Scientific Unions (ICSU), the United Nations Environment Program (UNEP), and other international organizations, includes assessment of climate impact on food production. Considerable attention was given to this aspect of regional and global climate problems at the 1979 World Climate Conference.

These programs provide opportunities for the U.S.

National Climate Program to cooperate with international food and climate activities. They also reflect a widespread sense of urgency and concern about food supplies, including conservation and management of natural resources used in food production. Further interaction with international organizations is highly desirable so as to plan the U.S. program to address both worldwide and national concerns.

Lead Agency

USDA is responsible for developing the Nation's food policies and estimating its food requirements and will serve as the lead agency for detailed planning and coordination of multiagency efforts. A basis for this effort exists in the following activities that can be expanded:

- USDA collects information on U.S. and foreign crops and livestock production and trade, assesses outlook and situation for agricultural supply and demand, and has responsibility for agricultural policy decisions and program operations.
- USDA and NOAA's National Weather Service (NWS) operate the Joint Agricultural Weather Facility (JAWF) to provide timely information and assessments of world weather conditions. This information is taken into account in the assessment of U.S. and world agricultural outlook and situation.
- USDA and NOAA/EDIS make crop yield modeling studies as part of the Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) conducted jointly with NASA, DOI, and AID.
- USDA and State agricultural experiment stations perform extensive research on agricultural production, including biological response of crops and animals to climate and reduction of adverse climate effects.
- NOAA's National Marine Fisheries Service (NMFS) conducts climate-related fisheries ecosystem modeling and research related to conservation and management of living marine resources, and also provides market outlook reports and statistical information on fishery catches and trade.

National Program

The National Program for this thrust has the following objectives:

- Increased understanding and improved measurement of climate impacts on all food-producing systems.
- Assessment of the impact of climatic fluctuations on national and world production and use; evaluation of strategies for dealing with variable food supplies stemming from climate fluctuations.
- Identifying and supplying climate data and information services that are needed for more efficient and stable food production and for the conservation and management of natural resources used in food production.

The program thrust will be developed and coordinated in accordance with the following guidelines:

- The primary purpose of these efforts is to determine needs and provide climate information for use in making decisions on the production, distribution and use of major U.S. and world grain crops, meat, and fish.
- The activities will include identification and measurement of climate impacts, interpretations of climate data and assessments, and evaluations of the usefulness of climate data and impacts to support food policy decision making.
- Maximum use will be made of available climate information capabilities and products of ongoing research and applications.
- Plans will be coordinated, to the extent feasible, with related plans and applications of other countries and international agencies.

These guidelines may be revised and expanded as the thrust is planned, or as options for future work are developed in detail. Initial efforts will be planned around ongoing work in USDA and NOAA described above.

In addition to this USDA and NOAA work, recent studies by USDA, the National Defense University, DOT, and EPA have produced methods for analyzing the economic consequences of climate impact on food producing systems. The experience gained from these studies is especially useful as a base for developing and testing climate assessment methods that are relevant to policy issues.

USDA base funding related to climate impacts on food production in FY 1980 is estimated at $5.9 million and is projected to remain at that level through FY 1984. This includes climate impacts research and use of climate information by USDA-funded climate impact research at State agricultural experiment stations. NOAA funding for FY 1980 is estimated at $1.4 million and is projected to remain at that level through FY 1984. NOAA base program funding includes climate/crop yield modeling and climate impact assessments by the Environmental Data and Information Service (EDIS), and climate-related research in fishery oceanography by NMFS.

Milestones

FY 1980

- Form interdepartmental management and planning team to direct studies leading to development of detailed management and technical plans, including program options for FY 82 and beyond.
- Define climate information requirements and associated analytic capabilities required to support assessments of U.S. and world food.

- Evaluate adequacy of ongoing activities and available resources and capabilities for meeting assessment and research and development requirements.
- Identify critical research and development needs for measuring climate effects on food producing systems (crops, livestock, and fisheries), and assessing impacts on aggregate food production.
- Identify research and development needed to improve the adaptability of food producing systems to climate conditions.

FY 1981

- Implement management structure to plan and coordinate climate and world food production activities.
- Carry out requirements studies and technical planning for optional activities, and prepare required multiyear budget plan and specific budget requests.

FY 1982

- Continue ongoing activities in support of U.S. and world food assessments.
- Carry out additional requirements studies and technical planning for future program options.

FY 1982/83

- Initiate work on one or more optional program efforts.

FY 1984

- Make application tests of available food and climate products and capabilities.

Options for future program development

(See also discusssion of options in Chapter I.)

USDA base resources, including technical plans and funds for the 5-year, multiagency AgRISTARS project beginning in FY 1980, appear adequate for improving significantly assessments of climate impacts on the world's major grain crops. A similar capability for assessing climate impacts on marine fisheries or livestock production does not exist now. It would require additional resources for research on fish and animal biological response to climate, for developing and testing operational uses of this knowledge, and for planning an integrated program.

Optional activities designed to improve understanding and response of marine and livestock production systems to climate effects would probably include the following:

Marine Fisheries

- Quantify and model effects of environmental factors on recruitment in selected fisheries off southeastern U.S. coasts.
- Intensify development of modeling techniques, including ecosystem interaction, for quantitatively assessing key fisheries of the Georges Bank and other waters off the northeastern United States.
- Systematically evaluate effects of climate fluctuations on the distribution and abundance of eastern Pacific Ocean fishery resources.

Livestock Production

- Model animal biological response to climate and related environmental factors in terms of animal growth, mortality, and reproduction.
- Develop management and decision models to assess the impact of climate on livestock production, shipping, and health.
- Test applicability of management and livestock models for reducing livestock losses due to adverse climate.
- Analyze the economic impact of climate extremes on the livestock industry, and meat prices and supplies.

It is estimated that these activities could be pursued with funding of $1 to $1.5 million annually.

B. Areas of Program Concern

1. Climate-related hazards

A recent estimate of damages resulting from climate-related natural hazards—such as avalanches, landslides and mudflows, accelerated coastal erosion, droughts, floods, lightning, hail and frost damages, hurricanes, tornadoes, windstorms, and urban snow—indicated that U.S. losses average nearly 600 lives and $5 billion annually. These hazards cannot be avoided completely nor would their prediction eliminate the associated losses. But an improved capacity to anticipate and respond to these events would reduce their adverse impacts significantly. Careful anticipation and more informed planning can enable us to avoid increased risks and capitalize on opportunities for reducing them. Increased knowledge about the processes and driving mechanisms of climate-related natural hazards is a prerequisite for more effective assessment and mitigation of the risks they pose.

In response to several storm-related disasters, the Federal government has become increasingly active in climate-related natural hazards research and planning efforts. The USDA, for example, has programs to investigate and monitor avalanche potential, drought, floods, and wind erosion. Similarly, DOD, through the Army Corps of Engineers, is analyzing flood and coastal erosion hazards. NOAA, in DOC, monitors significant weather events, and is responsible for issuing severe weather warnings and recommending evacuation. It also maintains a data file on all types of hazard events. NSF suports research and information dissemination on natural hazards and the social response to such hazards. The NSF-supported Institute of Behavioral Sciences at the University of Colorado has been a focal point of developmental work in hazard analysis. The Institute also maintains a Natural Hazards Research and Applications Information Center to facilitate the use of information on all phases of natural hazards work and initiates special conferences and symposia.

Another important facet of the Federal effort resides in the Federal Emergency Management Agency (FEMA). In addition to studying all types of natural hazards, FEMA is responsible for coordinating emergency warnings and post-disaster assessments and assistance. Finally, DOI has one of the larger efforts in hazards research. Within the Water and Power Resources Agency, Office of Water Research and Technology, and primarily within the U.S. Geological Survey (USGS), data are collected, analyzed, and filed on a number of climate-related geophysical hazards. In addition, USGS is involved in studies of societal response to hazards in support of its mandate to issue public notices or other information releases concerning geophysical hazards.

Working from these established operations, activities planned as part of this Area of Program Concern include:

- Continuation of site-specific studies delimiting areas of hazard potential. USGS will maintain a strong role in this activity, working with NOAA and the Army Corps of Engineers.
- Continued research into the mechanics of natural hazard processes. The work of USGS on landslides, mudflows, coastal erosion, floods, and avalanches will be complemented by NOAA's work on hurricanes, tornadoes, windstorms, and lightning, and by the Corps of Engineers' work on hydraulic processes.
- Continuation of efforts to understand the societal implications of natural hazards and the societal response to hazard events and information. Leadership for this will continue to come from the NSF-supported Institute of Behavioral Sciences as well as USGS. This activity will also include further development of hazard assessment techniques and planning assistance/technology transfer functions.
- Maintenance and improvement of the public hazard notification and disaster assistance network. USGS will continue issuing notices of geophysical hazards, NOAA will provide severe storm and flood notices, and FEMA will continue providing pre- and postdisaster assistance and relief.

In addition, two activities constitute significant opportunities in the area of hazard mitigation which should receive careful evaluation.

Natural hazards research necessitates development and use of methods and equipment for locating and predicting hazards. USGS and NOAA currently use remote-sensing data in their operations, and improvement of such techniques is essential if advances in hazard prediction are to be achieved. In addition to expanding the applications of current spacecraft systems, special emphasis should be given to greater use of future systems in hazards research.

A key component in disaster mitigation is an aware and responsive citizenry. Through FEMA, NSF, NOAA, and DOI, a much broader and more comprehensive program should be instituted to promote public awareness and education in natural hazards, especially in zones of high hazard potential.

2. Energy production, distribution, and demand

The droughts and extreme cold spells of recent years have increased our awareness of weather and climate fluctuations. There are identifiable climate effects on energy resource extraction, transportation, generation, distribution, and use. Severe winter storms interfere with the mining and transportation of coal. Hurricanes result in loss of natural gas production from Gulf Coast wells. Energy distribution problems result from storms and floods, and increased energy demand and use occur during heat spells, cold snaps, and droughts. Better planning for these recurring events and reduction of their impact depend upon better measures of the relationship of weather and climate to energy production, distribution, and demand. To use predictive information, it will be necessary to understand the impact of weather and climate on energy systems.

Recognizing that there is a relation between weather and climate and energy demand is simple. Quantifying that relation is more difficult. It is even more difficult to develop systems that use climate information to make decisions on fuel allocation and storage, design efficient distribution systems, develop energy conservation strategies, or evaluate those strategies—yet progress has been made. For example, procedures now exist for considering 30-day and seasonal climate outlooks in managing primary and alternate fuel supplies. Better quantitative assessments of the effects of climatic fluctutions on the demand for different fuels are needed. Structuring of climate information to make it more readily adaptable to these applications is essential. These activities require close collaboration between DOE and NOAA's Climate Analysis Center and Center for Environmental Assessment Services.

Fuel demand models have been developed for a small number of discrete locations (Greeley, Colo.; Cheyenne, Wyo.; and Minneapolis, Minn.). Efforts are underway to modify the models to operate in real time and to extend the area coverage. These efforts could be accelerated to provide a set of regional fuel-demand models covering all areas of the country in 3 years at a total cost of about $0.5 million.

The impact of climate on the production of energy has been studied in considerable detail and in some cases is well understood. In the case of hydroelectric power generation, for example, the dependence of system design and operation on climate data is widely recognized. The operation of fossil fuel systems is generally less dependent on meteorological conditions, but the climatology of air pollution is a major factor to be considered in plant location, design, and operation. Suitable strategies must be designed for sharing loads or switching fuels in order to maintain power supplies while meeting air quality standards during extreme events of air stagnation. This is an even more critical problem with increased dependence on coal.

Some "alternative" energy sources—wind, Sun, and ocean waves, currents and thermal stratification—depend even more critically on climate. Climate determines their availability and is often a major factor in the efficiency of the conversion system. For example, widespread use of solar energy depends on being able to accommodate to intervals of cloudiness, high and low temperatures, and humidity. Wind generation systems must be designed to be efficient under normal wind conditions and to withstand high winds, but they often must be located at sites for which adequate data are not available. For all these systems, specific data needs and interpretations will be developed by particular designers or users (e.g., DOE, NASA, HUD, and NOAA).

Present plans call for the 1981 DOE effort to assess impacts of climate perturbations on the energy system to be funded at just under $400K. Possible additional efforts should deal with impacts on various components of the nuclear as well as the fossil fuel cycle, with a wide variety of geographical areas characterized by both climatic and socioeconomic differences, and with a wide range of alternative energy sources. To exercise this option, funding for FY 1982 of about $1 million would be needed. The full scope of this activity could require doubling the initial funding.

3. Impact assessment methodologies

A major goal of the National Climate Program is to assist policy-making officials and other decision makers in anticipating and responding to the social, political, and economic implications of climate variations and changes. This requires assessment processes in a broad range of national interest areas cited by the National Climate Program Act—natural environment, agricultural production, energy supply and demand, water resources, transportation, human health, and national security.

Several cooperative projects have demonstrated the feasibility of assessing climate impacts in certain limited contexts. They include the Large Area Crop Inventory Experiment (LACIE), a joint NOAA/NASA/USDA effort; the Climate Monitoring and Early Warning for Disaster Assistance Needs in Developing Countries Program, a cooperative State Department/ NOAA program; and the initial energy demand estimation programs conducted jointly by NOAA and DOE.

But it is a long step from assessing the impact of climatic fluctuation on the yields of a few key crops to predicting how global climate will affect world food supplies, prices, and international trade. There are major differences between determining how regional climate anomalies will affect local energy demand and water supplies and estimating national and international economic and social impacts of worldwide climate variations. Consequently, much remains to be done to establish valid and credible methods for assessing the comprehensive impacts of climate fluctuations.

In 1980, the National Climate Program Office (NCPO) held a workshop on climate impact assessment methodologies to begin establishing a interdisciplinary process and research agenda. NCPO has lead responsibility for following up recommendations resulting from the workshop. Mission agencies have responsibility for identifying specific climate-related policy issues and problems that need methodological assistance. Much of the methodology development work that will be undertaken will be directly applicable to high priority climate impact assessments—energy, water resources, arid and semiarid lands, and especially CO_2 and world food production. NCPO will identify complementary efforts among agencies in these priority areas. EPA has very relevant experience from its studies of the effects of regulatory actions.

Recent international developments with regard to the establishment of a World Climate Program will facilitate close coordination with research plans and activities in other nations and early development of suitable interdisciplinary approaches to climate impact assessment.

4. Regional climate effects of humans

Human activities can cause changes in the Earth's albedo, or surface reflectance, in the Earth's surface roughness, and in the air's composition. Some changes could lead to climatic effects on a regional (100-3,000 km) scale.

While regional climate changes have certainly occurred, there is no well-documented regional—or global—climate change for which human activity is clearly the cause. Acid rain is a regional environmental problem, but it has not been shown to be associated with climatic change. There are suggestions that deforestation of temperate regions in Europe and North America and overgrazing in semiarid regons, which resulted in their desertification, have changed the albedo over the past few thousand years. Several theoretical analyses conclude that albedo changes could cause changes in temperature or other climatic characteristics. It also has been suggested that continued deforestation of equatorial forests might lead to regional climate changes. Further research on albedo changes and their climatic consequences is warranted.

Several effects may occur together. Windblown Saharan dust travels across the Atlantic Ocean, and studies have shown that this dust plays a role in atmospheric radiative transfer. The dust from the Rajasthan Desert of India reaches higher than 5 km, and it, too, disturbs the radiative balance. Some of the dust may result from overgrazing, which has also altered the local surface albedo.

Significant increases in surface mining and processing of coal and shale in the western United States will likely cause significant additions to regional dust loadings. These could, in turn, affect climate. Documentation of present dust levels and distribution should be undertaken soon, and the radiative and nucleating properties of the dust should be evaluated. In addition, the presence of strongly absorbing carbonaceous particles, believed to originate in industrial combustion, can enhance the low-level warming due to global "greenhouse" gases. Here, too, more study is warranted.

The most prominent human-caused change to the atmosphere is an increase in its aerosol content, stemming from aerosols injected directly (e.g., dust, ash) or from those produced from gas-to-particle conversions (e.g., sulfates from SO_2 emissions, nitrates from NO_x emissions). These additional particles could disturb the natural radiative balance in the air and affect cloudiness and precipitation regimes.

Industrial effluents may affect clouds and precipitation. However, it is difficult to distinguish the effects of particles from human sources from those of natural substances, and the evidence gathered thus far is inconclusive. Negative findings in some studies of certain substances do not rule out other existing or future pollution emissions as possible influences on weather or climate. As a general rule, anomalies in observed precipitation patterns that are apparently attributable to air pollution must be examined with the utmost caution.

Many particles observed on a regional and even global scale derive from gaseous sulfur compounds. Their quantity is likely to increase as coal usage increases. There is also a continued increase in the release of oxides of nitrogen (NO_x) from powerplants and transportation systems. Studies in both areas should be augmented, particularly on the quasi-gaseous and liquid forms of atmospheric nitrates.

One regional climate effect that requires attention is Arctic haze. Much, if not all, of the tropospheric air over the Arctic basin contains many particles, primarily sulfates, in the late winter and spring. As a result, visibility is reduced and turbidity is raised during that period. This haze plays a role in the climate of the Arctic. Trajectory and wind analyses suggest that the origins of the particles are industrial sources in western Europe and parts of the Soviet Union. However, while human sources are now blamed for the recent Arctic haze, greatly reduced visibility due to haze in the Arctic was reported even before the industrial explosion expansion that followed World War II. Thus doubts still linger about how much of the Arctic haze is of human origin.

The issue is important as it may lead to suggestions for additional constraints on industrial activity. The Arctic is an area of particular climatic sensitivity, and regional effects in the Arctic may lead to more extensive climatic responses. Further chemical and physical characterization of the haze particles and analyses of air trajectories are needed to settle the issue of the origin (human *vs.* natural) of the haze. To determine its impact on climate, a concerted effort to measure and model the difference in polar radiative balance with and without the haze is the single most important research need. There would likely be a considerable willingness to cooperate in such an effort on the part of the Scandinavian countries, but the cooperation of the Soviet Union would be welcome. A budget of about $2 to $3 million per year over 5 years would be required for such a program.

The National Climate Program Office, working with other interested Federal agencies, such as DOE (concerned about the effects of coal and shale mining and processing), USDA (concerned about deforestation), and EPA (concerned about air quality), will seek to identify regional climatic effects of humans, and conduct research to understand any cause-and-effect relationships.

5. Semiarid and arid lands

Climate is a crucial factor in the management of semiarid and arid lands. Dry-land ecosystems exist in a delicate balance with climate and are very sensitive to overuse or mismanagement. A long-standing major use of semiarid and arid lands is for grazing domestic livestock and wildlife. Other more recent activities include strip mining and recreation (e.g., off-road vehicles). Because of the limited flora and fauna and harsh conditions in arid and semiarid regions, their ecosystems are often slow or unable to recover from massive disturbances of the land surface.

Only a relatively small part of these lands has the water supplies, soil conditions, and terrain required for irrigation development. Increased human activities can amplify the stresses imposed by climatic variations and lead to severe damage and permanent degradation. Developing effective land management strategies for the arid and semiarid regions requires a better understanding of climate and its complex interaction with land use and natural systems.

The interaction of human activities, climatic events, and other natural factors can impose such stresses on dry land ecosystems that they collapse, leaving desertlike conditions. The Sahelian drought of the early 1970s demonstrated the tragic and massive economic and social impacts of desertification, and this sequence of events spurred the United Nations to develop a plan to understand and combat spreading worldwide desertification.

Responsibility for Federal programs concerned with arid and semiarid lands resides mainly with DOI and USDA. Each department manages vast areas of public land in the 17 western States. DOI is leading a national effort, involving Federal agencies, States, and private organizations, to prepare a National Plan of Action To Combat Desertification (NPACD), as part of the United Nations' desertification control effort. In addition, the United States and Mexico have agreed to cooperate in improving the management of arid and semiarid lands. Both DOI and USDA conduct research related to irrigation, land reclamation, soil and water conservation, forest and rangeland management, and maintenance of wildlife habitats. Other Federal programs related to arid and semiarid lands include EPA and DOE efforts to reclaim strip-mined lands, DOD's management of large military reservations in the arid west, and NSF-supported arid lands research.

The Climate Program has significant opportunities to help assure that climate information appropriate for the management of arid lands is available and more effectively used:

- **Resource Attributes of Climate.** Improved methods are needed for measuring the effect of climate fluctuations and extremes on the produc-

tivity of arid and semiarid lands. The need is urgent in the case of grazing lands. This land use contributes directly to food production and to the maintenance of an economic and related social structure. A capability to predict grazing land productivity under variable climate would aid in land use and livestock management by providing information for adjusting livestock numbers and for investing in appropriate land management practices. Another needed application of climate information is to support assessments of the Nation's renewable resources. These assessments do not, at present, sufficiently consider the effect of climatic variability on the output or carrying capacity of arid and semiarid lands.

One particular activity that the United States and Mexico could conduct, under their bilateral agreement to deal with desertification, would be the development of a climate and land use data base for arid lands research and management decisions.

- **Climate and arid land ecosystems.** Some land uses permanently change or even destroy arid land ecosystems. Actions to preserve or restore them must be based on improved understanding of the role of the climate variables. For instance, research to develop or locate new plant species for arid regions should include careful assessment of response to the climate of the areas considered.
- **Climate and cultural interaction.** Rapid demographic, economic and cultural change is occurring in arid and semiarid regions. At one extreme, agricultural displacement with attendant economic cost and social disruption often results from an extended drought. At the other extreme, arid climate can attract industrial and urban development. The opportunities and requirements should be explored for using climate information to help reduce costs, stresses, and risks associated with these changes.

6. Water resources management and planning

Water is a critical resource. Throughout history man has attempted to cope with irregularities in the availability of water. Ancient societies waxed and waned as the abundance and quality of water varied. Modern industrial societies are no less dependent on water, and today considerable sophistication is used in the design of structures and strategies to control water supplies and water quality in the light of what is known about climate. This strong link between hydrologic planning and climatology is even more crucial now:

- The rapid expansion of irrigation has imposed increased demands on ground water supplies, often at rates well in excess of recharges. This "mining" of ground water lowers the water tables and makes extraction more costly and energy-intensive. In some areas depletion of the ground water supplies threatens the collapse of regional economies.
- Many energy production options, such as oil-shale development, would place much greater demands on water resources, often in regions where water shortages are already a problem.
- Environmental and economic considerations limit the options available in the design of hydrologic facilities, fostering designs that are less resilient to climate change. This comes at a time when hydrologists are re-evaluating how best to deal with climatic factors in the analysis and design of hydrologic systems, and when there is growing recognition of the reality of natural and human-induced climate change.
- Reservoir sites are becoming difficult to find. Most acceptable locations are already developed, and present land owners strongly resist having their land taken for such purposes. This means that existing water management systms must be used more efficiently before additional development is justified.
- The California drought of 1976-78 was very severe, but the region and the Nation survived with relatively minor adverse consequences. In most cases, the management options chosen turned out to be wise ones. If the drought had continued through a third winter, however, much more drastic consequences probably would have ensued. This points out the nationwide need to use the best possible climate information in the development and the implementation of water contingency plans.

The responsibility for water resource systems design and management is distributed among a large number of Federal, State, and local agencies. Among Federal agencies that manage or plan for water resource systems are USDA's Soil Conservation Service and Forest Service, the U.S. Army Corps of Engineers, EPA, and in DOI's Water and Power Resources Agency, Bureau of Land Management, and Water Resources Council. In addition, important hydrologic expertise exists in DOI's USGS, DOC's NOAA, and State water resource institutes. All recognize that climate is a key element in the planning and operation of water management systems. There are, however, differences about how to deal with questions of climate and climate change and how to use climate information as a mangement tool. A growing need is emerging for short-range (several months) predictions of climate variables for operational decisions by water users and managers. The concern of the Climate Program is to assure that climate data and information needed for management and design decisions are available, and that a better use of knowledge

of climate is incorporated into such decisions. Three studies are planned in FY 1980 and FY 1981 that will shed light in this area.

One study will investigate design and operation strategies for water resource systems that can accommodate uncertainties in climate parameters.

Another study will be commissioned to examine how the various agencies' hydrologic models deal with climate change, how sensitive the design parameters are to climate change, and what information about climate and climate change is most important for the analyses.

Several climate-related tasks will be added to an extensive ongoing water resources/economic development effort to investigate the importance and use of climate information in a specific context. Discussions have already begun with DOC's Economic Development Administration in connection with their study of future development of the Ogallala Aquifer. The kinds of questions that would be raised are:

- How could now-available climate information best be used to assure more efficient use of water resources?
- Are there more useful types of information that could be made available?
- How much could future demands on the system be reduced through use of climate information that might be available in, say, 30 years—for example, improved seasonal predictions of regional precipitation?
- How are plans and designs affected by different judgments about the future course of climate, either as discernible from interpretations of past records or in response to considerations of human-induced changes?

CHAPTER V

UNDERSTANDING CLIMATE

The Climate Program must plan to achieve a better understanding of climate and climate processes. From a number of climate research subjects, a few emerge that require priority attention.

Principal Thrust	Lead Agency
Solar and Earth Radiation	NASA
Ocean Heat Transport and Storage	NSF

Area of Program Concern	Participating Agencies
Air-Sea Interaction	NOAA/DOD/NSF/NASA
Climate Model Development and Validation	NSF/NOAA/NASA
Past Climates	NSF/DOI/DOE
Polar Ice and Snow	NSF/NOAA/DOD/NASA/DOT
Stratospheric Processes	EPA/NOAA/NASA/NSF/DOT

A. Principal Thrusts

1. Solar and Earth Radiation

We must monitor the solar flux and the components of the Earth radiation budget so as to understand their roles in influencing climatic variability and to apply that knowledge to diagnose and predict climate. The basic components of the Earth radiation budget are the solar irradiances, both incident upon and reflected by the Earth-atmosphere system, and the emitted terrestrial radiation.

Need

The Sun provides the basic source of energy that drives the circulations of the atmosphere and oceans. Both the incoming solar and outgoing earth radiation are affected by factors such as clouds, trace gases, aerosols, and surface reflectivity, as well as by processes that take place on the Sun.

The residual energy in the Earth's atmosphere, oceans, and land and ice masses, its transport, and its variations with time force the entire range of atmospheric and oceanic motions, and produce convection, clouds, and storm systems. These constitute the weather, and when aggregated over time, constitute climate. Understanding the basic nature of solar and terrestrial radiation and its transfer through the atmosphere to and from the land surface and oceans is one of the most fundamental goals of climate research. Monitoring and analysis of the Sun and the components of the Earth's radiation budget are crucial to developing this understanding. They will be used to diagnose the present (and near-future) state of the climate, for the formulation of empirical prediction techniques, and ultimately for the development, initialization, and validation of deterministic global and regional climate prediction models. Insights gained in studying the Earth's radiation budget are also vital to developing confidence in prediction of the long term effects of anthropogenic influences such as CO_2, ozone, and aerosols. Understanding and analyzing the radiation budget thus serve three other Principal Thrusts: Climate Prediction; CO_2, Environment, and Society; and Ocean Heat Transport and Storage.

There are opportunities present today for making significant strides toward these goals as shown by:

- Dramatic advances in technology for measuring the Earth radiation budget and the factors that affect that budget from space.
- Promising new methods for monitoring the solar constant and spectral irradiance.
- Strong advances in our knowledge of radiative transfer.
- Continuing advances toward fully coupled atmosphere-ocean-cryosphere numerical global climate prediction models capable of handling complex radiation effects.
- Increased comprehension of the physics and chemistry of the stratosphere and its effects on radiation.

Lead Agency

Many of the necessary activities involve observations from satellites now in operation. Others involve planned satellite missions. For these reasons, NASA has assumed, for the National Climate Program, lead agency responsibility for the Principal Thrust in Solar and Earth Radiation. Working with other agencies, principally NSF and NOAA, NASA will be responsible for overall coordinated planning and for implementation of many of the activities cited.

National Program

The current and planned solar and Earth radiation program comprises the following principal elements:

Analyses of accumulated data involving radiation budget observations. Observations from the NIMBUS-6 and -7 Earth Radiation Budget (ERB) instruments and operational NOAA satellites are being used as the foundation for developing a continuing series of Earth radiation budget data sets. Output from the scanner on NIMBUS-7 is a key element in forming empirical models representative of

the angular dependence of the reflected solar and emitted thermal radiation from the Earth. The data sets formed from these observations will serve as a continuing resource for climate research.

Ongoing tasks are:

- Formation of data sets based on the NIMBUS-6 and -7 ERB and operational satellite measurements.
- Development of angular models from NIMBUS-7 ERB scanner data and overall improvement of comprehensive algorithms and calibration techniques.
- Application of NIMBUS-7 ERB angular models in the analysis of NOAA-SR and TIROS-N/AVHRR observations and assimilation of these data into an expanded climate data base.

Planned satellite activities. The Earth Radiation Budget Experiment (ERBE) is a planned satellite mission with launches scheduled for 1984. The experiment incorporates three sets of radiometers on different satellite platforms. Multiple platforms permit observations of each geographic region at different local times. This sampling overcomes possible biases which may have been present in past, Sun-synchronous satellite data. Major activities associated with the ERBE are:

- Launch the medium inclination Earth radiation budget satellite and the high inclination TIROS-N/NOAA.
- Analyze ERBE data using angular models from NIMBUS-7 ERB.
- Compare ERBE data with TIROS-N/NOAA AVHRR estimates of radiation budget.
- Analyze the diurnal component of the Earth's radiation budget and evaluate its impact on future observing systems.
- Merge ERBE data with the NIMBUS-6 and -7 ERB data sets and existing operational radiation data to form an extended data base.

Physical processes studies affecting the Earth's radiation balance. Aerosols—solid and liquid particles suspended in the atmosphere—directly affect the transfer of radiant energy in the clear atmosphere and also affect the optical and microphysical properties of clouds. The direct and indirect processes that are involved are complex and poorly understood. To gain the necessary understanding and to formulate related models, certain special physical processes studies are being carried out. These include:

- An extended cloudiness and radiation study aimed at gaining insight into the formation of extended cloudiness and the interaction of clouds and radiation.
- Studies involving the sources and composition of aerosols, especially those associated with volcanic eruptions, and development of models for relating the size and location (i.e., latitude) of volcanic injections and their ultimate radiative impact.

The two primary studies involve the following specific activities:

- Developing global cloud and aerosol climatological data sets from ground and satellite observations.
- Making sensitivity and diagnostic studies to test dependence of climate on cloudiness and aerosols.
- Making coordinated field observational programs both to improve and verify cloud and aerosol parameterizations in climate models.
- Conducting ancillary studies of vertical distributions of water vapor, ozone, and other trace gases, combined with information on aerosols and cloud distributions, to understand better the role of these constituents in the Earth radiation budget at the top of the atmosphere and at the Earth's surface.

Applications to climate analysis and prediction*

- Examining the relationship of variations in the global and regional climate system (e.g., heating processes within the atmosphere and at the surface; variations and transformations in energetics and circulation).
- Validating and improving general circulation and simplified climate models through comparison of model results with Earth radiation data sets.
- Using global and regional variations in Earth radiation data to make more realistic climate sensitivity studies.
- Developing empirical relationships of physical parameters carried in climate models and radiation budget components to improve treatment of physical processes in climate models.
- Developing the statistical relationships between radiation budget components and subsequent climate fluctuations to help improve statistical climate predictions for months and seasons.
- Using radiation budget components as initial input in numerical long-range prediction models.
- Studying the relationships between new observations of radiational variations in the Sun and climate fluctuations.

Solar constant measurements. Uncertainty about the variability of the energy output of the Sun is a major factor in being unable to test hypotheses concerning climate change

*These activities merge into those associated with the Principal Thrust of Climate Prediction. They are properly associated with both Principal Thrusts. Funding is not allocated by Principal Thrust, but by activity; the same activity, supported once, contributes to multiple goals. The National Climate Program Office will exercise oversight to assure the harmonious melding of NASA leadership for Solar and Earth Radiation and NOAA leadership for Climate Prediction.

and climate fluctuations. The Sun exhibits some variability that substantially affects the upper atmosphere. But it is not certain whether the total energy output of the Sun varies significantly (i.e., by tenths of a percent), and whether the lower atmosphere and the bulk of the climate system are affected by solar variability. It is important, therefore, to continue to monitor the solar constant and its spectral variations directly, from rockets, balloons, and satellites (SMM, Shuttle, ERBE, UARS).

Milestones

The following series of specific milestones is planned if the Congress approves the FY 1981 budget and the outyear projections included in that budget.

FY 1980

- Establish the ERBE and SAGE II mission science teams.
- Establish special project for processing NIMBUS-6, and -7 ERB data sets.
- Initiate planning for the International Satellite Cloud Climatology Project.
- Launch Solar Maximum Mission (SMM) satellite providing continuity in precision measurements of the solar constant.

FY 1981

- Continue solar constant observations from sounding rockets.
- Initiate a program for ensuring long-term stability in solar flux measurements.
- Continue the production of Earth radiation budget data from research and operational satellites.
- Continue the analysis and interpretation of radiation data and study its relationship to other climate variables (e.g., cloud parameters, precipitation, and temperature).
- Begin studying the potential utility of radiation budget parameters derived from geosynchronous satellites.
- Initiate studies to estimate radiation budget at the Earth's surface.
- Finish developing improved angular models of reflected solar radiation based on the analysis of NIMBUS-6 and -7 results, and begin using these models to interpret measurements and radiation budget estimates from NOAA-SR and TIROS-N data.
- Begin to characterize the global distribution of stratospheric aerosols and clouds.

FY 1982

- Define long-term solar monitoring program.
- Use Earth radiation budget and cloud data sets as initial conditions for climate model experiments and validate and improve those models. Use improved models for further sensitivity studies.
- Improve parameterization of the effects of clouds in the hierarchy of climate models.

FY 1983

- Complete a comprehensive Earth radiation budget data set covering the period 1973-82 from operational (ITOS/TIROS-N/NOAA) and research satellites (NIMBUS-6 and -7).
- Refine estimates of the effects of aerosols and trace gases on the radiative budget and on climate.
- Evaluate potential use and production of radiation budget data from operational geosynchronous satellites and define instruments for such measurements from future geosynchronous satellites.

FY 1984

- Implement the Earth Radiation Budget Experiment (ERBE).
- Implement long-term solar monitoring system.
- Define the specifications and design of follow-on operational system for long-term monitoring of Earth radiation budget parameters.

Options for future program development

(See also discussion of options on Chapter I.)

The planned program will accumulate essential information about solar and Earth radiation and the value of radiation measurements for climate analysis and prediction. The program will be limited in several ways, however. First, there are factors influencing the radiation budget for which only limited understanding will be available—most notably cloud properties, surface characteristics, and certain trace gases. A truly comprehensive picture of radiative processes will still be lacking. Secondly, the measurement program is a transient experimental one. There are no definitive plans to make it operational, which may be necessary to support climate predictions and climate analysis.

The options for the future program to remedy such deficiencies include an in-depth study of radiation processes, development of a long-term monitoring system, and development of remote-sensing capabilities for new types of measurements. The knowledge gained through studies of radiative processes would be integrated. To understand the role of solar and Earth radiation in the climate system, and the importance of radiation-related processes to other key climate processes, the future program would link the various processes through integrated field experiments and integrated models. Ultimately, improved methods for parameterizing climate processes (including radiation) will be developed and tested against data from the field experiments, leading to sophisticated climate models ready for application.

The options fall into four categories: Observing System, Data Set Development, Process Studies, and Modeling and Diagnostic Studies.

Observing system. The observing system would include:

- Deployment of an operational Earth radiation budget monitoring system (ERBE follow-on) for long-term monitoring of solar flux and the

components of the Earth radiation budget.

- Development of an advanced imaging radiometer for monitoring cloud and surface parameters—including channels for distinguishing clouds from snow, estimating vegetative cover, measuring cloud heights, and estimating optical parameters of the cloud layer.
- Development of a capability for measuring Earth radiation components from geosynchronous satellites.
- Development of space-based instrumentation for operational monitoring of aerosols and radiatively active trace gases in the troposphere—particularly CO_2 and O_3.

Data set development. The data sets would include:

- Surface energy parameters based upon imaging radiometer data.
- Cloud parameters.
- Stratospheric and tropospheric aerosols and trace gases.

Process studies. Research into the fundamental physical and chemical processes that influence climate will undoubtedly raise a host of new questions. More studies will be needed as the program matures. The future program could include the following field experiments:

- Regional Atmospheric Radiation Experiment. This would implement a "complete radiation experiment," wherein one measures simultaneously the radiation field and the atmospheric and surface parameters that determine the field. Experiments of this type could be carried out for several regions of climatic interest. Radiative fluxes would be measured above the atmosphere from geosynchronous satellites, and at the same time measured at the surface with an appropriately designed network of radiation sensors. Information on the vertical structure and composition of the atmosphere (including microphysical properties of clouds and aerosol layers) would be obtained from Lidar and radar instruments at surface stations and on shuttle flights.
- Joint Ocean-Radiation Experiment. A coordinated experiment involving the experiment just described, with an oceanic component to measure heat fluxes (sensible and latent) through the air-sea interface and horizontal transport in the ocean mixed layer.

Modeling and diagnostic studies. The knowledge gained from the integrated field experiments would be used to improve climate models further. The expanded data sets would provide the initial conditions for input to the models and diagnostic information for evaluating the output. Those climate processes that cannot be modeled deterministically would be represented by empirical relationships derived from measurements in the field experiments. One of the future options is to carry out simulation studies with the improved models to help design the required observing system for a potential global climate experiment in the 1990s.

Costs of program options

(See also discussion of options in Chapter I.)

The most costly option will be development of an operational prototype for Earth radiation budget monitoring, although the bulk of these costs would not accrue until after FY 1984. Other observing system options indicated would require $2 to $4 million annually. Options identified in data set development, process studies and modeling could also total $2 to $4 million annually if all were implemented.

2. Ocean heat transport and storage

Improved measurements and knowledge about the processes of oceanic heat transport and storage are needed for a better understanding of the ocean's role in climate and climate variability.

Need

The ocean covers about three-fourths of the Earth's surface. The ocean absorbs energy from the Sun and releases some of this energy to the atmosphere as heat over long periods of time and at locations that are often distant from the places where the energy was originally received. Storage, advection, and transfer of heat by the ocean vary slowly, but are believed to be major causes of year-to-year atmospheric fluctuations. An understanding of oceanic transfers and storage of heat and its interchange to the atmosphere is fundamental to understanding interannual and longer-term climatic variations.

Such climatic variations relate to the Earth's energy balance, and, more specifically, to the transport of large amounts of surplus heat from the Tropics to higher latitudes. The atmosphere's contribution to this movement of heat towards the North and South Poles has been measured. The processes by which it occurs are understood. Indirect evidence indicates that the ocean plays a large role in this heat transport; however, the processes that contribute to this transport are poorly understood.

Figure 1 shows estimates of the relative size of the poleward heat transports by the ocean and by the atmosphere. At latitude 20° N, the ocean carries 75 percent of the total northward heat flux and the atmosphere only 25 percent. In the Southern Hemisphere, the ocean appears dominant down to latitude 30° and remains substantial as far as 60° S. These figures and the large geographical dissimilarities of the two hemispheres suggest that very different ocean heat flux and storage mechanisms are operating.

It is necessary to determine whether the transport is accomplished by persistent circulations, by large eddies or by small transient eddies, by circulations involving deep waters or confined to upper layers of the ocean. Presumably all contribute to some extent. An essential aspect of this Principal Thrust is the development of suitable instrumentation and techniques for monitoring the large-scale oceanic circulation on a long-term basis. As knowledge of

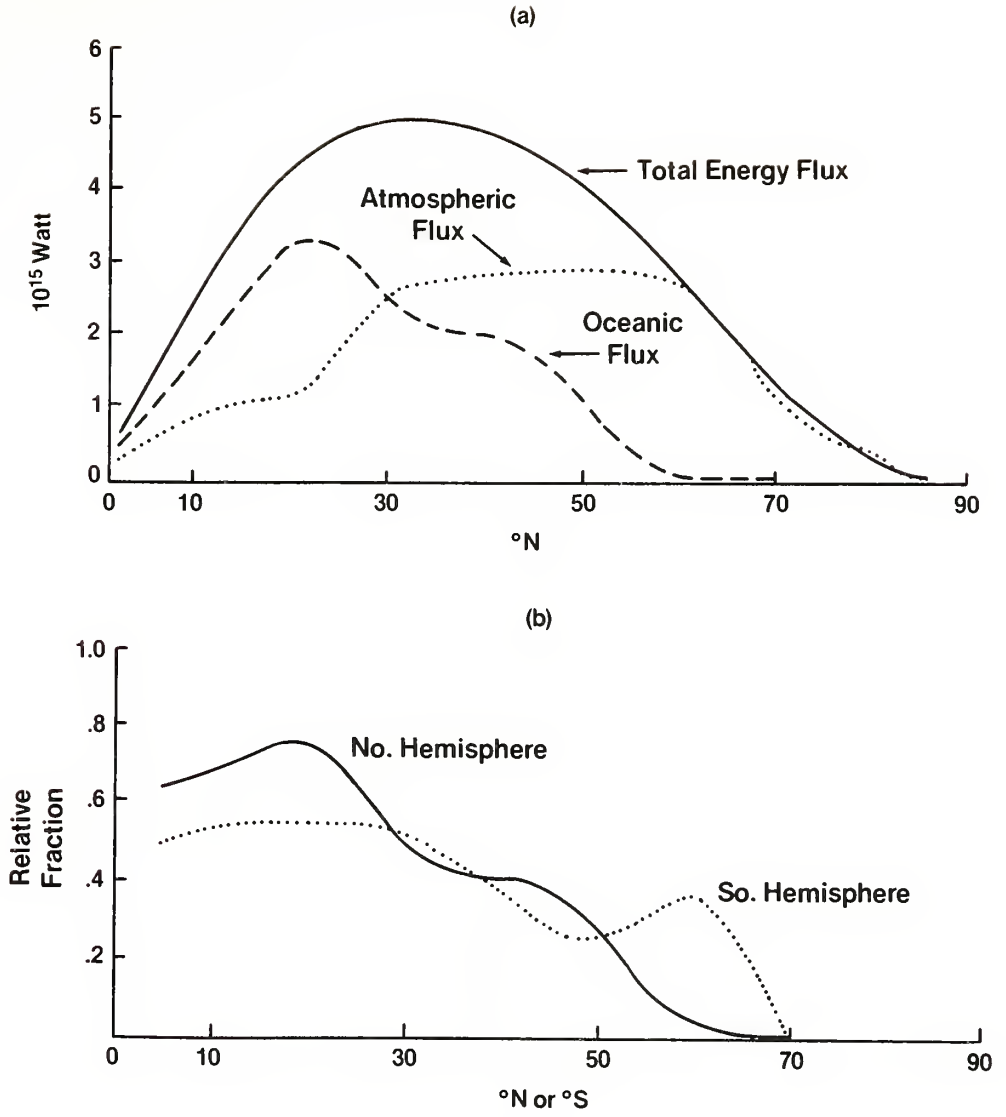

Figure 1.—Net poleward ocean and atmosphere energy transports: (a) for Northern Hemisphere; (b) relative fraction at ocean energy transport *vis a vis* atmosphere energy transport for Northern and Southern Hemispheres.

the mechanisms increases, it will become easier to specify an economical system to monitor the transport and its variations. At present, no observing technology suited to economic monitoring exists.

The long lifetimes of ocean heat transport and storage anomalies may provide a basis for extended-range forecasting. However, these lead times also create research problems. They lengthen the time necessary for experiments to observe and understand the anomalies. Successful conclusion of experiments involving the real ocean and atmosphere is delayed by two other circumstances not usually encountered.

The first is the fact that oceanographers and meteorologists cannot initiate large-scale, anomalous events, but must wait for their occurrence. The frequency of occurrence, for example, of the powerful Southern Oscillation/El Niño phenomenon is on the order of once every 3 to 10 years. Such an event, when it occurs, may last from a few months to 2 years.

The second circumstance is that, although the ocean and the atmosphere are tightly coupled, one forcing the motion of the other, it is difficult to establish conclusively a cause-and-effect relationship between atmospheric and oceanic events. Different, unrelated events may occur together merely by chance. To understand an anomalous event, one must observe a number of such events, and the time period for any one of these events is very long. Thus, for this Principal Thrust, a critical unbroken continuation of long series of oceanic observations that are now being taken must be assured and we must begin as soon as possible on new efforts.

During the past 5 years, climate-related oceanography has become a research topic of very great interest among physical oceanographers both in the United States and abroad. This interest was recently expressed by the attendees at the joint meeting of the Committee on Climate Change in the Oceans (CCCO) and Pilot Ocean Monitoring Study Group (POMS) in Miami, Fla. (The CCCO is jointly sponsored by the Select Committee on Ocean Research of the International Council of Scientific Unions (ICSU) and the International Oceanographic Commission (IOC). POMS was established on an *ad hoc* basis by the Joint Organizing Committee for the Global Atmospheric Research Program.) At this meeting, research plan outlines were presented by oceanographers and meteorologists from the United States, the Soviet Union, France, the Federal Republic of Germany, Canada, Mexico, and Japan. This group recommended that the World Meteorological Organization (WMO)/International Council of Scientific Unions (ICSU) Joint Scientific Committee for the World Climate Research Program commission studies to "explore the feasibility of conducting a basin-scale experiment to evaluate the poleward transport of heat in the atmosphere and ocean using a variety of techniques," and to "explore the feasibility and design of an experiment to determine the global ocean circulation using a combination of hydrographic methods and the geodetic/altimetric satellite techniques".

The promise of powerful new observing techniques such as acoustic tomography, doppler acoustic current profiling, and the increasingly effective use of commercial ships led to optimism on successful research. The United States and Japan proposed, for 1986 or shortly thereafter, gravimetry and altimetry satellites that would provide the precision global sea surface topographical data necessary to calculate geostrophic currents.

Simultaneously, new analysis methods have been devised for the efficient design of sampling schemes and for the more complete use of resulting data. Optimal estimation schemes (e.g., inverse theory) and objective-analysis methods have simplified considerably the task of interpretation. Other techniques of comparable sophistication promise to place hydrographically determined, relative geostrophic flows on an absolute basis. This helps in computing the transport of heat by deep-ocean currents.

Finally, encouraged by the success of the recent Global Weather Experiment, the international scientific community wishes to use that available institutional machinery to coordinate broad international participation in a program of large-scale heat transport and storage experiments.

Lead Agency

Success in the Principal Thrust involves close interaction of Federal and private (university) activities—a perfect role for the National Science Foundation. There will be major participation by other agencies, especially NOAA, and also DOD and NASA. Significant help in the planning and coordination associated with the international aspects of the Program will come from the GARP Program Office in NOAA.

National Program

The general strategy for this research thrust is to encourage instrument development, empirical studies, field experiments, and theoretical modeling of the storage and horizontal flux or transport of heat in the world's oceans. The purpose is to delineate the temporal and spatial variability of those ocean features associated with important climate fluctuations. The goal is to describe and model the great thermal and mechanical inertia of the ocean to provide a basis for climate prediction. In field work, equal emphasis is to be placed on process-oriented experiments and monitoring through collection of long, representative time series of ocean data.

Initial emphasis will be placed on three process-oriented experiments in the North Atlantic, each addressing a larger space scale, culminating in a Global Ocean Circulation Experiment (GOCE) scheduled to begin during the late 1980's. Instrument systems and techniques developed during the North Atlantic experiments should be in place for the Global Ocean Circulation Experiment. GOCE is scheduled to take advantage of an opportunity to measure the absolute geostrophic velocity field in the ocean on a global basis using the United States and Japanese altimeter satellites to be launched in the late 1980's.

The process-oriented experiments will be located in the North Atlantic because of: (1) the international oceanographic community's overall great interest in that ocean; (2) its smaller size, compared to the Pacific, and accessibility; (3) its strong meridional heat flux; and (4) its simplified flow structure with a western boundary current region (Gulf Stream) separated by a topographic barrier from a mostly eddy-free, return-circulation region.

In conjunction with these process-oriented experiments, acoustic tomography will be tested during the early part of the 1980's. This promising new technique for large-scale ocean monitoring measures fluctuations in the thermal structure of the ocean by measuring perturbations in the travel time of sound (and received intensity) between sources and receivers separated by long distances in the deep sea. Should this test prove successful, a large (basin) scale tomographic system in the western North Atlantic region may be deployed for testing in 1985-86.

The specific elements of the ocean heat transport and storage research plan are as follows:

- Beginning of a series of three successively larger scale, North Atlantic regional heat flux (transport) and storage experiments (HFE-I, II, III) to test and further develop ocean theory and instrumentation. HFE-I is envisioned as being confined to the Gulf Stream/Western North Atlantic region.
- Development of a global ocean monitoring strategy and implementation plan.

- Continuation of existing large-scale ocean/atmosphere research programs through their scheduled data analysis and synthesis phases (e.g., NORPAX, EPOCS, FGGE, ISOS, MONEX-INDEX, POLYMODE, GEOSECS).
- Continuation of existing national and international large-scale ocean observation programs (e.g., sea-surface temperature and surface wind measurements from World Weather Watch (WWW) volunteer ships, tide gage stations, ships-of-opportunity programs, and satellite measurements of sea-surface temperature).
- With participation and support from other nations, development of a viable, coordinated expansion of ships-of-opportunity XBT programs, beginning with the large-scale monitoring effort already underway in the North Pacific.
- Continuation of certain recently begun regional ocean circulation and heat flux studies (e.g., EPOCS, PEQUOD, SEQUAL, and the Transient Tracers Study).
- Support of a U.S. Planning Conference by the National Academy of Sciences to develop a formal U.S. proposal for international (WMO-ICSU) consideration. This proposal would respond to the aforementioned POMS recommendations and cover the U.S. part of a North Atlantic heat flux experiment series culminating in the extensive, internationally supported global ocean circulation experiment.
- Continuation of oceanic general circulation modeling activities at NCAR, GFDL, NASA, and academic laboratories.
- Through the Ocean Sciences Section of NSF, continuation of support to small, individual basic research on ocean climate dynamics.

Milestones

FY 1980

- U.S. Planning Conference held by National Academy of Sciences to develop formal U.S. ocean heat flux proposal for international consideration.

FY 1981

- Complete initial phase of detailed scientific and technical studies to develop optimum monitoring strategy for ocean climate.
- Initiate Gulf Stream/Western North Atlantic region heat flux experiment (HFE-I).
- Demonstrate three-dimensional tomographic system over a (300 km^2) area in the western North Atlantic.

FY 1983

- Make available measurements from HFE-I delineating climate-scale, low-frequency variability of ocean currents and associated heat flux.

FY 1984

- Complete design for a test of observing systems for ocean circulation, and heat flux and storage.
- Accumulated scientific results will include: (1) an improved and expanded data base for research on large-scale ocean circulation and assessments of seasonal and annual variability; (2) improved understanding of the mechanisms responsible for upper-ocean and surface temperature anomalies; and (3) an assessment of the effects of eddies on horizontal and vertical heat flux.

Options for future program development

(See also discussion of options in Chapter I.)

The program just outlined will produce substantial progress. But the development of ocean/atmosphere climate models and the application of models to climate prediction will still need better observational records of oceanic behavior over a wide range of time and space scales.

Specific programmatic options that will be weighed include:

- Continuing certain large-scale ocean monitoring activities now scheduled to be phased out in the near future (e.g., NORPAX Pacific pressure gage network and the NORPAX and ISOS ship-of-opportunity XBT programs).
- Expanding the internationally coordinated ship-of-opportunity program, mentioned above, to cover the global oceans—partly in support of the Global Ocean Circulation Experiment
- Carrying out the second and third in a series of three North Atlantic regional heat flux and storage experiments (HFE-II and HFE-III) to test and further develop ocean theory and observational capabilities. The HFE's will be major initiatives of the World Climate Research Program (WCRP). HFE-II is envisioned as a midsubtropical gyre (Sverdrup) experiment, and HFE-III is envisioned as a complete coast-to-coast (Atlantic-wide) meridional heat flux experiment.
- Examining key heat transport and storage characteristics that appear to be unique to the southern oceans (e.g., variations in the circumpolar current and in the heat storage of the larger gyres).
- Implementing detailed planning, on the basis of information obtained from the HFE series and subject to the results of a feasibility study, to carry out the Global Ocean Circulation Experiment.
- Exploiting these and other ocean-based experiments to test new instrumentation and monitoring systems.
- Encouraging the continuation of those experiment components (observations) that demonstrate most promise in delineating global climate changes.

These activities would contribute substantially to increased understanding of the global climate system. The long data series emphasized in this option appears to be an essential link in the production of research results to understand global ocean circulation and thus to improve climate forecasting. Development of effective coupled ocean/atmosphere models for forecasting and for describing the global distribution of CO_2 or long-lived contaminants such as fission byproducts might then be possible. The field experiments will provide for the evaluation of the performance, reliability, and long-term effectiveness of ocean monitoring techniques. When the global climate data base finally includes the ocean, our theoretical understanding of the climate system will be much more complete and balanced. Issues of climate predictability and climate sensitivity will be much more tractable.

Based on current planning, implementing all of these options would cost $4 to $5 million per year.

B. Areas of Program Concern

1. Air-sea interaction

Solar energy absorbed by the Earth and its atmosphere is converted to energy forms that drive the climate system. The amount of solar energy absorbed by the Earth's surface is about double the amount absorbed in the atmosphere. Thus, the energy available at the surface exerts great influence on the atmosphere and climate. To predict variations of climate accurately, we must understand this influence and the partitioning of energy and momentum between surface and atmosphere.

The Earth's surface is largely ocean, which, compared to the land, can store energy longer and transport it farther before giving it up to the atmosphere. The oceans supply energy to the atmosphere by direct thermal contact, radiation, and evaporation. The atmosphere is the source of much of the momentum of oceanic waves and currents.

Most U.S. studies of air-sea interaction over the past 15 years have been in the equatorial regions, where significant knowledge of air-sea coupling has been gained. These studies include the Indian Ocean Experiment, the GARP Atlantic Tropical Experiment, the North Pacific Experiment (which, its name notwithstanding, included much of the southern tropical Pacific Ocean), EPOCS, and a number of smaller individual research projects. NSF and the Office of Naval Research (ONR) of DOD have been the principal supporters.

Several equatorial field programs were in progress during 1979, the year of the Global Weather Experiment, including the North Pacific Experiment and NOAA's Equatorial Pacific Ocean Climate Studies (EPOCS). (These experiments have also been cited as Heat Storage and Transfer Experiments. Oceanic measurement programs are generally designed to serve multiple purposes, because they are expensive and logistically difficult.) Mid- and high-latitude air-sea process studies have been limited (the North Pacific Experiment, the Joint Air-Sea Interaction project, and the Polar Experiment).

Theoretical studies and observations of ocean-basin and large-scale fluxes are required. Available information on critical exchanges of heat, momentum, and other thermodynamically important components (such as carbon dioxide and aerosols) is biased toward low wind conditions. However, much of the transfer probably occurs during relatively brief intervals of high winds and rough seas. Vertical transfer over the sea changes dramatically with the passage of individual storms.

NOAA, ONR, NSF, and NASA are evaluating specific suggestions for further research and a plan of action. A recent workshop (Jet Propulsion Laboratory, 1980), planned and carried out by the California Institute of Technology, developed a set of appropriate recommendations to guide NASA planning efforts. A reasonable research effort can probably be mounted at a cost of $2 to $3 million in the first year, increasing by about $1 million in the two subsequent years. These plans and proposals await proper analysis of recent experimental results and the conduct of a few individual studies such as the United States and Canadian Storm Response and Exchange Experiment scheduled for 1980 in the North Pacific. This experiment aims at episodic, short-term air-sea interaction, which may be precisely what is needed to learn about important climate processes, or to help design proper large-scale temperate latitude air-sea interaction studies.

2. Climate model development and validation

Modeling studies play a central role in climate research. The real climate system is complex and often defies experimentation. Well-formulated models are uniquely suited to help acquire understanding of the underlying dynamics of the climate system. Models permit the scientist to simplify the system, evaluate hypotheses, and run repeated experiments. Only through tested and validated models can one develop credible judgments as to how the real climate system will respond to conditions (e.g., changes in solar radiation or in atmospheric composition) that are outside the range of recorded climatic history. Models also provide an essential tool for prediction and for learning about the limits of predictability. Finally, models are useful for simulating observing systems and therefore help in efforts to design such systems.

A continuing effort to improve climate models and understand their characteristics is imperative for the Climate Program. Because of modeling's central role in the Program, it is of special concern that the progress in model development and testing of recent years continue, and that there continue to be opportunities to pursue new lines of investigation.

Several groups have made significant contributions to the national effort. The NOAA Geophysical Fluid Dynamics Laboratory has been a leading contributor, in particular,

to general circulation models and to model studies of the sensitivity of climate to natural and anthropogenic disturbances. Other groups that have been active in large-scale climate modeling are the NASA Goddard Laboratory for Atmospheric Sciences (GLAS), and the NSF-supported National Center for Atmospheric Research (NCAR). A number of university programs, supported by NSF and NASA, have also played a significant role in large-scale model development. In addition, many laboratories and private university and research groups have been involved in the development of the more highly parameterized types of climate models.

Model development and model studies will continue over the next 5 years. There will likely be some additional support for modeling efforts as the result of the Principal Thrust in Carbon Dioxide, Environment, and Society. The Climate Prediction Thrust should also serve to stimulate modeling efforts. In addition, a special stimulus to climate modeling will occur soon when the Global Weather Experiment becomes available. Analyses of these unprecedented data sets will be a particular boon for testing global climate models. The development of more quantitative information on past climates will also facilitate understanding the models' behavior and validity under a wide range of boundary conditions.

Each of the agencies involved in climate modeling will encourage scientific exchange with other countries through the World Climate Research Program. Notable climate modeling efforts are being pursued in Great Britain, West Germany and the Soviet Union. International collaboration is considered essential.

A possible hindrance to progress looms, however. Efforts devoted to modeling the climate system are frequently constrained by limitations of computing facilities. Relatively little computing power has been devoted to modeling global ocean behavior or to using large models for prediction. Either or both of these could create demands that would outpace the present rate of growth of proper facilities.

3. Past climates

Numerous paleo-environmental sensors provide records of past climates and their impacts. For example, changes in marine fossils in deep-sea cores, fluctuations in pollen in lake sediments, variations in tree-ring widths, isotopic changes in polar ice, the movements of alpine glaciers, and many other natural phenomena are related to climate and provide evidence of past conditions.

The field of paleoclimatology is now experiencing a period of rapid growth of concepts and techniques, and contributes four important types of information:

- Paleoclimatic research delineates the frequency, range, and modes of natural climate variability. The instrumental record is very short compared to the time scales of known climate variability, but paleoclimatology enables us to examine the full spectrum of climate variability and helps us put the present in perspective.
- Investigations of past climate changes provide important clues to how the climate system works. Efforts to study the long-term interaction of the atmosphere, oceans, ice caps, biosphere, and land surfaces are crucial for understanding possible major changes in the future, such as the climatic response to the buildup of atmospheric carbon dioxide.
- Paleoclimatic research provides information about the impacts of climate on biological, geological, and societal systems. The paleoclimatic record allows examining the response of the natural system to changing climate and often provides direct evidence of climatic impacts, such as changes in ecosystems, the recurrence of flooding, and sea level and glacier fluctuations.
- Studies of past climate supply an empirical basis for testing models of climate. The instrumental record covers too narrow a range of experience to verify model simulations of climatic conditions markedly different from the recent past. A useful research strategy is to model past climates and then use the comparison of the model climate with the paleoclimatic data as a means to measure the model's validity.

NSF funds a diverse paleoclimate research program, where climates of past decades to millions of years are studied. Glacial-interglacial changes in ocean temperatures are mapped, and tree rings and pollen data are used to examine changes of North American climate since the beginning of the present interglacial period. USGS also conducts a broadly based program to examine many aspects of past climates and their impacts. Both NSF and USGS investigate paleoclimates using glaciologic, isotopic, paleontologic, geomorphic, geophysical, and other forms of evidence on past conditions. In addition, DOE funds some paleoclimatic research relevant to its carbon dioxide program.

The record of the past 1,000 years provides detailed information about recent climatic variations lasting decades to centuries and is particularly relevant to societal planning. Paleoclimatic studies can document the magnitude, frequency, and geographic patterns of climate fluctuations during the last few millenia, and provide valuable information on the character and recurrence intervals of extreme events such as severe winters, droughts, floods, and hurricanes. To achieve an improved understanding of climatic processes over this time scale, it is necessary to obtain a global data base that covers both the oceans and continents.

Studies of past climates provide opportunities to investigate the interactions of the atmosphere, oceans, ice caps, and land surfaces, including whether these interactive components are in phase or lead or lag behind one another. The

response of the climate system to various forcing functions, such as changes in the Earth's orbital parameters, injections of volcanic dust, and changes in albedo, can also be studied. Paleoclimatic research may also provide information relevant to planning for the long-term storage of nuclear wastes and to handling any CO_2-induced climate change.

4. Polar ice and snow

The role of polar caps, sea ice, and snow cover in the climate system is important, but is not fully understood. Climate models of all levels of complexity are sensitive to interactions between the cryosphere (ice and snow cover) and other components of the system. For example, in the heat balance models of Budyko and of Sellers, the role of ice and snow in changing the amount of radiant energy absorbed at the surface of the Earth is a critical factor in how the model climate responds to changes in solar radiation or atmospheric composition. In the complex general circulation model calculations of Manabe, on the other hand, a very critical aspect of the model's response is how the sea ice restricts the transfer of heat from the oceans into the atmosphere.

In almost all model simulations and empirical studies, climate variations have the greatest amplitudes in high latitudes. Thus the first evidence of a CO_2-induced warming may appear in these sensitive polar regions. Parts of the Antarctic ice sheet are believed to be vulnerable to changes in ocean and air temperature. Interannual variations in polar snow accumulations and sea ice extent are known to be significant and must be considered in studies of climate variability.

For all these reasons the ice and snow of the polar regions are of particular interest to the Climate Program. Additionally, monitoring the behavior of these regions would help ascertain the seasonal, interannual, and longer term variability, and would establish a base necessary for detecting secular changes. Improved climatological information in the polar regions is needed for operational decisions related to using their vast renewable and nonrenewable resources in an efficient and environmentally sound manner. Near real-time data on snow cover are valuable for short-term climate forecasting. Better information on the ice sheets is a prerequisite for understanding mass-energy relationships in the polar regions. Research is needed to incorporate snow and ice processes and feedbacks into climate system models.

The difficulties of obtaining observations in polar regions have limited study of these areas. In recent years, especially with the advent of satellites and reliable drifting buoys that can supplement observations from manned platforms, opportunities for polar research have been greatly enhanced. Programs like the Arctic Ice Dynamics Joint Experiment (a United States/Canadian venture) and the Polar Subprogram of the Global Atmospheric Research Program have demonstrated the success of these techniques. The NOAA and DOD operational meteorological satellites provide basic data on the extent of ice and snow coverage, and subsequent analysis of various aspects of the data is supported by many agencies.

Highlights of the planned activities related to polar ice and snow include:

- Continued satellite monitoring programs. Improvements designed to help discriminate between cloud and snow or ice cover are to be included in new versions of the operational satellites. Analyses of these satellite data by NOAA (NESS) and DOD (Navy) will continue.
- Extension of the Arctic polar drifting buoy program through approximately 1985, to obtain a multiyear continuous record of Arctic sea ice and water motions. Support for this effort will come from NSF, NOAA, and DOD. With international cooperation, somewhat similar efforts will obtain data around the Antarctic continent.
- Further analytic and theoretical studies will be made on various aspects of ice and snow as part of the climate system, with special emphasis on sea ice dynamics, and supported by the Cold Regions Research and Engineering Laboratory of the Corps of Engineers, Navy, NSF, and NOAA.

In addition to these planned activities, several other programmatic opportunities are under consideration and evaluation. (See also the discussion of options in Chapter I.) They include:

- Bolstering the ability of the World Data Center-A, Glaciology (operated for NOAA by the Institute for Arctic and Alpine Research at the University of Colorado), to handle the increasing amount of, and demands for cryospheric data. Developing and maintaining a system of data management to serve both research and operational needs more adequately would cost a few hundred thousand dollars annually.
- Expanding the cryospheric monitoring capabilities of satellites to include information on the depth, structure, and other characteristics of ice sheets. Experimentally, there have been clear indications of the potential for radar and microwave measurements from satellites, and these should be exploited to the degree possible. A decision either to continue (in FY 1982) the planning of an Ice and Climate Experiment (ICEX) or to proceed with specific adjuncts to other planned satellite systems that would permit more comprehensive cryospheric monitoring would require about $2 million not currently programed.

- Extending analysis and interpretation of available satellite data sets. This would require NASA to budget incremental support of about $2 million over three years.
- Making additional investigations of cryospheric processes, particularly theoretical studies related to ice sheets and sea ice. These efforts would be carried out largely by academic and research institutions with support from NSF, NASA, and NOAA amounting to $0.5 to $1 million per year.

5. Stratospheric processes

Stratospheric ozone shields life forms at the Earth's surface from the Sun's biologically damaging ultraviolet radiation. The vulnerability of the stratospheric ozone layer to human influences has become widely recognized in the past decade. Trace substances reaching the stratosphere can alter the natural ozone balance. The most important of these substances are the chlorofluoromethanes—chemicals used as propellants in spray cans, as refrigerants, and as foaming agents in plastics manufacture.

Several organizational bodies are coordinating national activities for addressing the threat to stratospheric ozone. Under Public Law 95-95 (The Clean Air Act Amendments of 1977), an Interagency Coordinating Committee for Stratospheric Ozone Protection was established under the lead of the Administrator of the Environmental Protection Agency. This committee provides biennial reports to the Congress on the progress of relevant research, monitoring, and assessment. The National Academy of Sciences formed a Committee on Impacts of Stratospheric Change, which published two comprehensive assessments (Committee on Impacts of Stratospheric Change, 1976 and 1979). An Interagency Working Group on Monitoring the Stratosphere (of the Federal Committee for Meteorological Services and Supporting Research) is responsible for coordination of a national stratospheric monitoring program, and, in particular, of stratospheric ozone and the processes that destroy and create ozone. NCPO has followed the activities of these coordinating groups, and has avoided duplicating their planning and coordinating functions.

The stratosphere is an important part of the climate system and is involved in many aspects of climate behavior. For example, increases in CO_2, as well as ozone changes, may be expected to modify stratospheric temperatures significantly. Model calculations indicate that a doubling of atmospheric CO_2 will cause temperature changes in the lower stratosphere several times greater than the changes anticipated at the Earth's surface. Thus, the stratosphere may be the best place to detect early and unambiguous climatic effects caused by changing atmospheric composition.

From the Climate Program perspective, the principal concern is that there be continuous monitoring of the stratosphere, analysis of the data in a timely manner, and research to assure that climatically significant changes in the stratosphere are both observed and understood.

The Federal effort related to monitoring the stratosphere is described in "The National Plan for Stratospheric Ozone Monitoring and Early Detection of Change" (to be published shortly by the Federal Coordinator for Meteorological Services and Supporting Research).

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The major elements of the planned monitoring program for the stratosphere are: (1) surface-based ozone measurements; (2) rocketsonde measurements of ozone, temperature, and other meteorological parameters in the stratosphere; (3) operational satellite measurements of ozone and stratospheric temperatures; and (4) research satellite measurements of ozone, other stratospheric gases, and aerosols. The surface-based ozone measurements, supported by NOAA, are part of a WMO network and provide data on both total ozone and vertical ozone distribution. The NASA sponsorship of rocketsonde measurements of ozone is to be terminated in 1983 (consistent with the end of the experimental phase of satellite observations of ozone). Beginning in 1983, NOAA's operational satellite program will include instrumentation to measure ozone. Rocketsonde ozone measurements will still be needed to provide calibrations for the operational satellite instruments. The present version of the operational NOAA satellites carries an instrument specifically designed for measuring stratospheric temperatures.

The most important need for the rocketsonde temperature measurements is for calibration to assure the reliability and comparability of global satellite measurements of stratospheric temperatures. The Cooperative Meteorological Rocket Network Program, which has been the source of these rocket data, has been supported mainly by DOD, but some of that support is being withdrawn in 1980 and the program is expected to end in a few years. Specific decisions about the rocketsonde programs for both ozone and temperature are very important to the Climate Program.

Another option that must be considered concerns timely analysis of stratospheric data collected by balloons, satellites, and rockets. At present, the NOAA Climate Analysis Center cannot cope with the full range of data and assure early detection of climatically significant events. It will be necesssary to augment their capability if this objective is to be met.

A continuing rocketsonde observation and analysis effort would involve costs of between $1 to $2 million per year.

Finally, a major factor in the course of future stratospheric research is the continued availability of new instruments and new measurements. NASA is considering an upper atmosphere research satellite program that would provide great impetus to stratospheric studies, and other studies of the upper atmosphere that go well beyond the immediate concerns of the Climate Program.

CHAPTER VI

TOTAL PROGRAM SCOPE AND STRUCTURE

The preceding three chapters described the highest priority efforts of the Climate Program, but these efforts are only a part of the total National Climate Program. They are supported by, and become part of a broad base of continuing activities in Climate Impact Assessment; Climate System Research; and Data, Information, and Services.

Figure 2 is a schematic representation of the relationships among these three components of the Program and how they contribute to the overall Program objectives. Figures 3, 5, and 6 expand on these relationships.

A. Climate Impact Assessment

Policymakers often need timely information about the impacts of climate extremes, fluctuations, and changes. The purpose of Climate Impact Assessment is to provide that information, including analyses of possible policy responses. The full scope of activities (see figure 3) includes: (1) evaluations of policy responses and strategies; (2) assessments of societal implications of climate; (3) assessments of impacts on economic activities; and (4) assessments of climate effects on processes and natural resources.

1. Policy responses and strategies

Impact assessment studies must provide the policy maker with information about the impacts of climate, and how those impacts would be affected by various responses and strategies available to him. These studies also serve internal program needs by identifying the information required to handle climate-related policy issues as they arise. These policy issues fall within the following categories:

- **Short-term and episodic events**—responses to weather events, such as severe snow storms or severe storms involving flooding or coastal erosion. These events are relatively rare and happen quickly; policy must be made in terms of general preparedness for expected climatic hazards.
- **Regional climate fluctuations**—responses to medium-term climate events (of 1 month to several years), such as droughts, severe cold spells or heat waves, and land erosion or shifting sands. Response policy is based on early preparedness and tactical action during the event itself. Examples include decisions on agricultural production and trade.
- **Global and regional climate change**—response to long-term global changes (of decades and longer) resulting from natural or man-induced climatic events such as CO_2 changes from energy decisions. Policy decisions are most difficult, as climate changes involve multiple and often conflicting causes, and there is a great deal yet to be learned about their societal consequences.

Each of these three categories has different information needs—in terms of type, format, and timeliness—and thus different assessment methods may be needed. Assessment methods were addressed at a workshop held by NCPO early in 1980.

Identification of climate-related policy issues and alternatives will be primarily the responsibility of the mission agencies. NCPO will identify policy gaps, overlaps, or conflicts as they arise and ensure that conflicts in national or mission agency policy interests are brought to the attention of appropriate decision-makers.

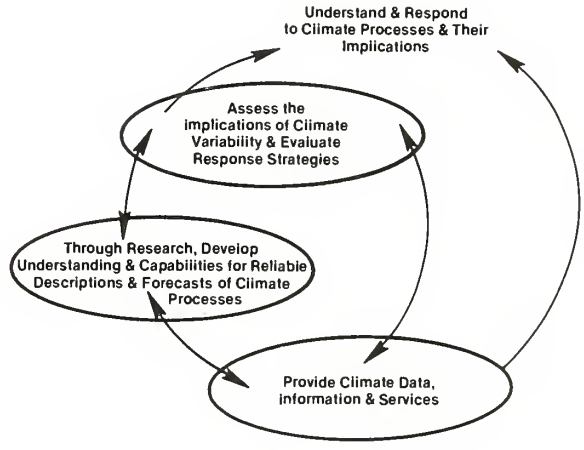

Figure 2.—Program components and objectives of the Program.

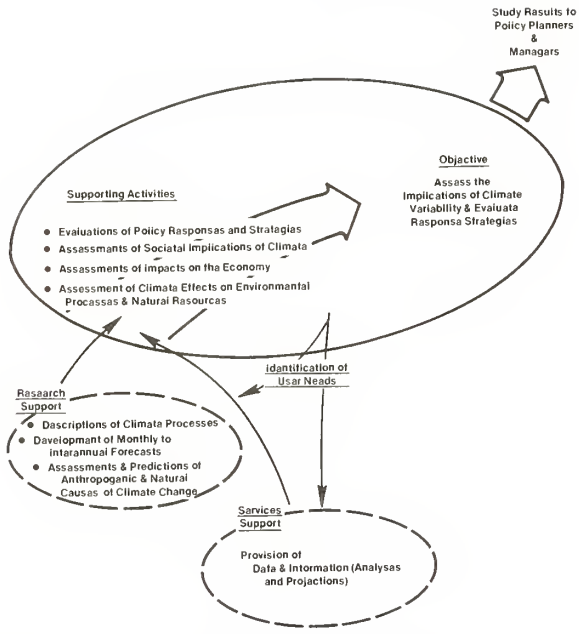

Figure 3.—The Climate Impact Assessment component and its relationships to the other Program components.

2. Societal implications of climate

Policy decisions affect a broad array of societal interests, groups, and institutions. The breadth of these societal interests is acknowledged explicitly in a recent (April 18, 1980) letter report of a Climate Research Board *ad hoc* panel on economic and social aspects of carbon dioxide increase, chaired by T.C. Schelling of Harvard University. Typically, however, climate impacts have been assessed in terms of single-interest, single-sector considerations. The Climate Program will seek to evaluate climate impacts over a broader societal context.

- **Ethical, social, and cultural considerations.** Climatic changes may create important ethical, social, and cultural issues. For example, the long-term character or potential irreversibility of particular events—such as the CO_2 "greenhouse" effect—raises ethical issues seldom addressed explicitly. For example, how will increased dependence on coal and possible CO_2-related climate changes affect other nations and future generations?

  To address such issues, the Climate Program will encourage research on ethical considerations in making climate-related policy.
- **Geopolitical consequences.** Because climatic events affect human activities, whether indirectly through the economic system or directly through the environment, they may result in complex international political consequences. For example, climate changes may cause redistribution of wealth, which may lead to conflicts both within and between nations. We must analyze the opportunities for potential obstacles to national, regional, or international understandings. The CO_2 issue concerns many nations, as does acid rain derived from transnational pollution.
- **Economic consequences.** Most climatic events affect several sectors of a nation's economy, and often affect more than one region, in the form of market and trade adjustments, or employment and population migrations. Thus, economic effects vary, depending on the society. For example, climatic events may have devastating effects on a developing country's national income, while the same events have no more than a modest impact on a developed country. Yet, developed nations often experience serious, climate-induced regional or sectoral redistribution of income. However, few economic models include climate in their design. Development of regional, inter-industry economic models, capable of handling the complexities of climate impacts on a society, thus becomes an interest of the Climate Program.

3. Impact on economic activities

The most widely accepted measure of climate impact is in terms of economics. Some economic models have been developed to describe and analyze the effects of climate on specific economic sectors. Among these are USDA analyses of the impact of drought on producers and the national economy; National Defense University analyses of potential effects of climate change on production, prices, and trade of major world food crops; and DOT and EPA studies of the consequences of climate modification on agriculture and other sectors of the economy. DOC plans research to measure the impact of unusual climate conditions on sensitive sectors of the national economy. However, the adequacy of these models to support decisions on climate-related matters is still unknown. The Climate Program will encourage development of studies that assess specific economic consequences of climate variation, particularly for:

- **Agriculture.** Food production is highly vulnerable to weather and climate conditions. Disturbances in world food production affect commodity markets, trade flows, and stocks, and often are the direct cause of starvation and malnutrition. Integration of climate information into analyses and forecasts of world food production helps identify the possible onset of adverse conditions and develop strategies to stabilize food stocks and food trade flows. USDA and NOAA cooperate in interpreting information about world weather conditions for use in assessing the outlook for U.S. and world food production.

- **Energy.** Adverse weather and climate conditions can affect energy supplies, costs, and productivity, and have secondary effects on employment and income. Energy allocation options must evaluate the needs for human health, industry, agriculture, and transportation—all affected by weather and climate.
- **Industry and business.** Some industries and businesses, notably transportation, construction, outdoor recreation, communications, and public utilities, are affected significantly by climate fluctuations. Direct economic consequences are evident in changes in demand for the product or services of a particular industry or business, or through changes in operating costs and fixed investment. Adjustments required to meet these conditions often are built into the management and financial structure of firms. Indirect economic impact of climate on employment, sales, and purchases from suppliers also may be significant, but is normally outside the scope of plans by individual firms or industries. Better information is needed for business planners about the total sensitivities of business and industry to climate conditions.

4. Effects on processes and natural resources

Climate fluctuations and extremes are part of the natural environment, and human activities must be adjusted to contend with extreme or persistent climate conditions.

Most of the efforts now committed to impact assessment are used for basic and applied studies of the direct effects of climate fluctuations and extremes on natural processes and on natural resources.

- **Effects on ecosystems.** Climate fluctuations can influence the outbreak and suppression of disease, insects, and pests that affect human health and the productivity of crops, forests, livestock, and wildlife. A major share of research on climate effects on ecosystems concerns agriculture and forestry and is done by USDA and the State Agricultural Experiment Stations.

  The importance of fish in world food supplies is sometimes overlooked. The U.N. World Food Council estimates that fish provide 20 percent of the world's total animal protein, and over half the total animal protein in the diets of some countries. Fluctuations of climate, including the climate of the oceans, affect the productivity of the world's fisheries. NOAA is developing climate-related ecosystem models to support fishery management.
- **Plant and animal response.** The effect of climate fluctuations on agricultural production, particularly food crops, is by far the most important direct climate impact in terms of worldwide social, economic, and political considerations. In recent years, world crop production has not been buffered sufficiently by reserve supplies to prevent major market disturbances and the threat of serious food shortages stemming from these climate fluctuations.

  The USDA and the State Agricultural Experiment Stations conduct basic and applied research on the biological response of plants and animals to different climatic conditions. The knowledge gained by these studies is important for achieving success in applications such as crop forecasting. Several Federal agencies (USDA, NASA, and NOAA) are cooperating in the use of research information on plant growth, weather and climate data, and aerospace remote sensing technology to develop and test improved methods for estimating crop yields beginning early in the growing season. This capability will be used to help forecast yield and production of major U.S. and foreign crops, and to support early warning of conditions affecting production and quality of crops.

  Development of climate response models applicable to managing livestock and for estimating grazing land productivity has not progressed beyond the research stage.
- **Land and water resources.** Soil characteristics are largely determined by long-term climate, and these characteristics may be altered by current climate, which contributes to both destructive (erosion) and protective (vegetative cover) conditions. Coastal zones are especially vulnerable to climate effects, both atmospheric and oceanic. Many natural hazards (droughts, floods, landslides, and wind and water erosion) are climate related, and appropriate response actions must be based primarily on understanding the way that weather and climate conditions interact with the land resource.

  The interaction of climate, natural resources, and human activities on arid and semiarid lands is sometimes so severe that biological productivity collapses, leading to desertlike conditions. The problem of desertification and plans to combat it are receiving international attention. USDA and DOI have major program responsibilities for conservation and management of U.S. public and private lands.

  Surface and ground water supplies are directly related to climate conditions. Projections of future availability of water supplies are vital in regional development planning and for the location and investment decisions of industries and businesses. Water resource programs of the Federal and State governments include planning, management, and development. Climate

data and climate/water resource relationships are applied extensively in these programs through hydrologic models, analysis of the climate record, and water supply forecasts. Major water resource planning and construction programs are coordinated and carried out by DOI, USDA, and the Army Corps of Engineers. EPA and USDA both have water quality program responsibilities. State governments also carry out water resource programs, some in cooperation with the Federal government.

- **Energy requirements.** The effect of climate on residential, business, and industrial fuel requirements has provoked increasing concern following several severe winters and rising energy costs. There is widespread interest in alternative energy forms such as solar sources and wood fuels. The economic incentive to conserve energy is strong, especially in view of continued high prices, but it needs to be supported with improved methods for estimating energy use and requirements, and the costs and benefits of developing alternative energy sources. DOE and NOAA have most activities in this area.

B. Climate System Research

Research on the climate system is the foundation for improved understanding, and provides the basis for significant advances in climate applications and services. The objectives of Climate System Research are: (1) comprehensive descriptions of climate and climate processes; (2) reliable forecasts of monthly to interannual climate conditions; and (3) assessments of the sensitivity of climate to natural or human influences, and estimates of long-term climatic behavior.

These objectives bear a strong resemblance to those stated in the Report of the U.S. Committee for the Global Atmospheric Research Program (1978) and to those set for the World Climate Research Program being developed jointly by the World Meteorological Organization and the International Council of Scientific Unions. Vigorous interaction is expected between the National Program and the international effort, with possible adjustments in program priorities and scheduling made in response to that interaction, particularly the evolution of the international program and U.S. commitments to it.

The global climate system involves the atmosphere, oceans, snow and ice masses, and many aspects of land surfaces and vegetation. Figure 4 shows the major physical components and feedback processes responsible for the maintenance of climate. Despite the system's complexity, progress can be made toward understanding and predicting climate variations. A growing scientific community is being attracted to the problem. There are improved technologies, especially satellites and computers, that allow new approaches to the problem. Although accurate climate predictions are unlikely in the next 5 years, there is a good chance that we will know by then whether some aspects of climate are theoretically predictable.

Climate System Research concerns the processes that control the slow evolution of climate. Typically these processes are persistent over relatively large regions of the Earth, and this has led some to think that the climate system is bounded by some arbitrary time and space scales. The notions that research "for understanding the climate system should focus on the regional (about 1,000 km) to global, and for time scales of several weeks to several decades" (Climate Research Board, 1978), are useful as guides, but should not be taken as rigid limits.

For example, cloud formation and precipitation mechanisms are important weather phenomena. Individually, they are not climate processes, but, collectively, they are very important to climate. The factors and processes that control cloudiness and precipitation must be included in Climate System Research. Learning about the behavior of individual clouds, or individual cloud systems—to the extent that this is not essential to understanding their collective behavior—is not included.

Conversely, there are some large-scale phenomena that are inappropriate in Climate System Research—magnetospheric behavior, for example. While the magnetosphere shows patterns of behavior that are of the same time and space dimensions as climate phenomena, interaction with the lower atmosphere or other aspects of the climate system appears to be small. Thus, for now, magnetospheric, ionospheric, and other upper atmosphere phenomena are not considered integral to the Climate Program.

If an influence on climate would remain after the cause is removed, or if the influence modifies a process that otherwise would be considered a climate process, then study of that influence is properly part of Climate System Research. For example, urban influence on climate is persistent, because the city is always there. It affects local heat, moisture, and momentum exchange, and perhaps local precipitation and convection processes. But if one could remove the city, its climatic impact would be removed. In contrast, if tomorrow all deforestation and the burning of fossil fuels were halted, the carbon dioxide already introduced into the climate system would remain for some time to come. Carbon dioxde alters the global radiation balance; thus, the study of how increasing atmospheric carbon dioxide may affect climate is included in Climate System Research.

Acid rain is not included in climate research, as it appears that the sulfur and nitrogen compounds in acid rain are not particularly interactive with other parts of the climate system.

Knowledge of how the climate system works is still sufficiently rudimentary that imaginative individuals are needed to investigate all facets of the problem. This creates an important role for small science and relatively unstructured research.

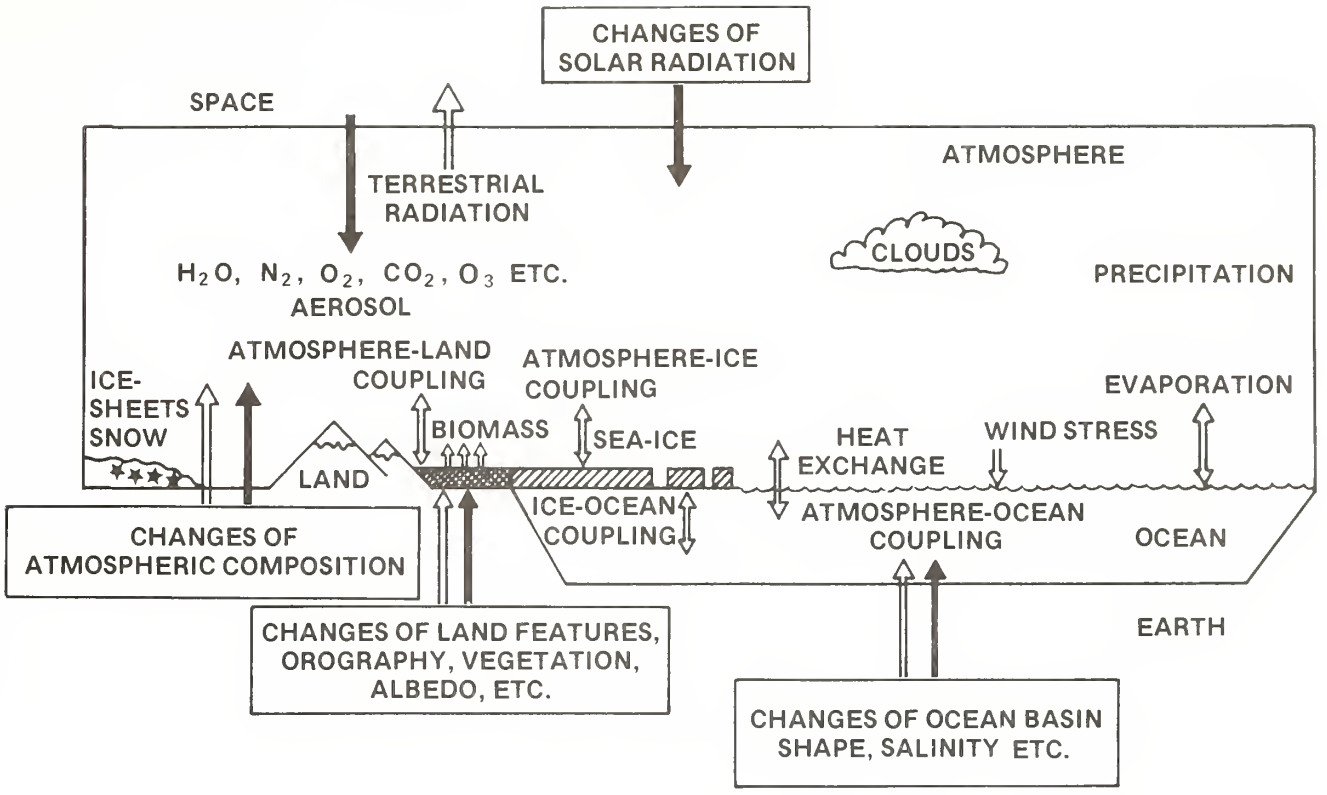

Figure 4.—Schematic illustration of the components of the climatic system. The full arrows (➡) are examples of external processes, and the open arrows (⇨) are examples of internal processes in climatic change (Adapted from Report of the Panel of Climatic Variation to the U.S. GARP Committee, 1974).

The status and needs of climate research were reviewed by the National Research Council in its 1978 report (U.S. Committee for the Global Atmospheric Research Program, 1978), and by the Climate Research Board at the July 1979 workshop review of the National Climate Program Preliminary 5-Year Plan. A panel of recognized experts convened by the NCPO provided additional guidance (National Climate Program Office, 1979).

Specifically, the NCPO research plan comprises the following activities (fig. 5):

- Empirical studies and analyses of the climatic record.
- Development of climate simulation and prediction models.
- Studies of physical climate processes.

These activities, in turn, support other program components by providing better descriptions of climate, more reliable forecasts, and appreciation of the sensitivity of climate to human influences.

Activities and their task descriptions include ongoing and needed work.

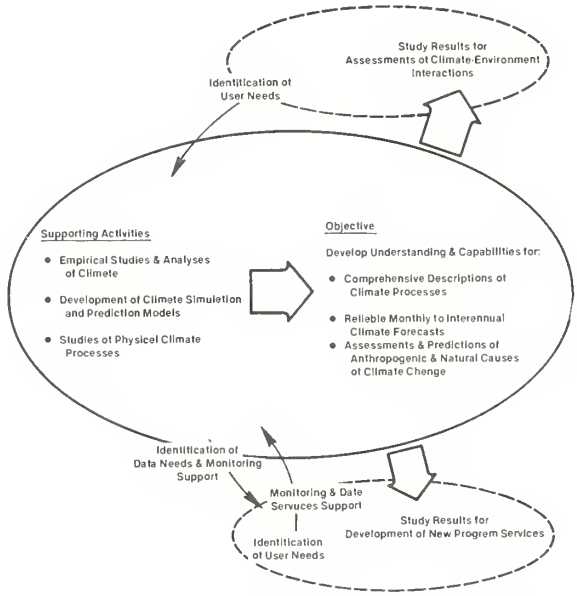

Figure 5.—The Climate System Research component and its relationships to the other Program components.

1. Empirical studies and analyses of the climatic record

Understanding how the atmosphere has behaved in the past will lead to insights as to how elements of the climate system interact with one another and the constraints that act on the climate system, and will permit better judgments concerning future climate scenarios. Tasks include:

- **Improving the availability of specialized analyses and research data sets, particularly of proxy data for reconstruction of past climates where no observational record exists** (This effort is supported principally by NSF, USGS, and NOAA).

  Access to a long-term climatic data base of known accuracy is essential to climate research. Conventional data and analyses will be forthcoming from the Data, Information, and Services component of the Program, but these must be supplemented by specialized analyses and further compositing of data. Through these analyses, a historical record of regional and global climatic variability will be improved.

  A paleoclimatological data base will be developed using tree rings, ice cores, and other paleoclimatic indicators at 1- to 10-year intervals for the past thousand years; at 100-year intervals for the past several millennia; and at 1,000-year intervals for the past 10,000 years.

- **Developing analytical techniques to describe climate variation** (NOAA, NSF, DOD, NASA).

  Research will focus on the "signal-to-noise ratio" for various climate parameters and will develop improved analytical techniques to describe climate variability, establish new climatic indices, and improve the record of climatic variability. The magnitude of the global climate signal that can be detected with the present observing network (or modifications to it) will be evaluated.

- **Increasing knowledge of interactions between climates in different geographical locations, between the upper and lower atmosphere, and between climate and changes in atmospheric composition, ocean temperature, and/or snow-ice extent** (NSF, NOAA, DOD, NASA).

  Observational data will be used to examine interactions between the Northern and Southern Hemispheres, and to examine "teleconnections" of climate between widely spaced regions of the globe, between troposphere and stratosphere, between zonally averaged circulation and regional climate anomalies, and between large-scale ocean circulation and production of large-scale thermal anomalies ("cold" and "warm" pools). The magnitude of climatic response to observed past instances of aerosol loading in the atmosphere by volcanic eruptions, to variable polar ice cover, and to persistent sea-surface temperature anomalies will be studied.

2. Development of climate simulation and prediction models

Realistic models of climate advance and measure our understanding of the climate system. Models provide the ultimate hope for achieving accurate prediction of both natural and inadvertent climate variations.

Application of models to determine the response of the climate system to a stimulus that is alterable by nature or by humans is necessary, but at present unreliable. A "crash program" to answer troublesome questions about the impact of some agricultural, industrial, or natural force on climate is not only expensive, but is also unlikely to yield highly dependable results. Research will be paced to answer, reliably and cost effectively, the seen and now unseen problems of inadvertent or natural modification of climate.

Fundamental uncertainties exist on the limit to which climate predictions are possible. As understanding of the climate system increases and models become more realistic, better assessments of climate predictability will be possible. In the interim, since demands for prediction exist—particularly in the seasonal to interannual time span—some progress in prediction capability can be made through better understanding of climate processes.

Climate simulation and prediction require:

- **Models of atmospheric processes and improved model formulations of atmospheric chemistry and dynamics, clouds, radiation, surface interactions, water, and other atmospheric trace constituents** (NOAA, NSF, NASA, DOE, DOD).

  Research will be supported to improve the physical parameterizations and approximations involved in the formation of climate models. Improvements will be sought in model treatment of the influence of surface topography on atmospheric motion, specification of boundary conditions, and parameterizations of small-scale processes. Other related problems of model development (e.g., reduction of computation time) will also be attacked.

- **Models of the ocean to understand the role of ocean currents, eddies, ice, and mixed layer characteristics in ocean heat storage and transport over climatic time scales** (NSF, NOAA).

  Oceanic general circulation models will be developed using a variety of modeling approximations and approaches. Tests will be carried out, in particular, ones to assess the importance of explicitly representing ocean eddies in ocean climate models. Criteria for these tests will be the models' abilities to simulate observed transports of heat and various geochemical tracers. Much of the modeling work will be done in conjunction with field experiments that obtain the needed empirical data.

- **Coupled ocean-atmosphere climate models** (NOAA, NSF, NASA).

  Improved model techniques for coupling the ocean and atmosphere media in a completely interactive fashion are needed to allow more realistic simulations of the total climate system.

Model experiments will be pursued to determine the fraction of the deep ocean that might be considered constant for various climate modeling purposes and to evaluate the influence of radiation budget variability on meridional heat transport.

- **A hierarchy of highly parameterized climate models. We must improve our knowledge about the appropriateness of less complex models in various applications, by studying their sensitivities, useful parameterization, intercomparabilities, and performance verifications** (NSF, NOAA, NASA, DOE).

  Complete general circulation models are very demanding of computer resources. A range of simplified models will be developed and used to study the sensitivity of climate to factors such as aerosols, carbon dioxide, and surface albedo feedback. Particularly important is the development of models to examine quantities such as time averaged evaporation, precipitation, and wind distributions. Experiments will be made with simplified dynamical models and highly parameterized models that couple ocean to atmosphere. Such experiments are necessary to gain insight into the generation, evolution, and predictability of sea-surface temperature anomalies and their influence on the atmosphere. As contrasted with the more complex general circulation climate modeling efforts, this activity will involve smaller groups and broader university participation.

  Climate models must be tested, compared, and validated systematically. Such evaluations will help determine the "level of confidence" that one can ascribe to them and point toward improvements. Several model tests have high priority. The first priority is to test model abilities to simulate statistics of observed climate over the annual cycle, and compare observed and simulated regional climatic features. The second is to evaluate model performance in characterizing paleoclimates, as a model calibration procedure and a test of theory. Finally, tests will be made of the ability of highly parameterized models to simulate transitions between paleoclimatic states. Observing system simulation studies will be carried out with models to define observational requirements and aid in the design of observing systems. Using standard data sets compiled for the purpose, tests will be made of model performances, and evaluated in terms of the simulated variances as well as the simulated means. Generalized features of the Earth's climate will be examined in experiments with laboratory models and compared with mathematical models. The generality of models will also be tested against observations of other planetary atmospheres.

  An intensive series of tests and evaluations will be made during 1983 and 1984, but intermodel comparisons will be made throughout the period of this Plan. Specific model tests and international intercomparisons will be carried out under the aegis of the World Climate Research Program.

- **Systematic studies of climate responses to influences of anthropogenic pollutants, ice-snow extent, ocean temperature, variable solar radiation (insolation), surface boundary characteristics, and volcanism** (NOAA, NASA, DOE, NSF).

  Systematic model studies of climatic response to natural phenomena, such as volcanic activity and changes in quality and quantity of solar radiation received by the Earth, are of high priority. So, too, are those studies that aid in the evaluation of climatic feedbacks within the system, such as those involving changes in radiative and heat exchange properties of soils, vegetation, and snow and ice extent. One of the most important lines of modeling research to continue is a systematic study of climatic responses to changes in aerosols, carbon dioxide, and chlorofluoromethanes. The few climate modeling efforts attached to the largest computing capabilities (as at GFDL, GLAS, and NCAR) will be applied. Less costly but important contributions can be made by groups using more highly parameterized models.

- **Models that simulate the annual cycle with higher order statistics that reveal subtle climatic differences** (NOAA, NASA, NSF).

  Support will be given for model experiments using perceptions gathered from studies of climate processes and, most importantly, from the Global Weather Experiment. The Global Weather Experiment covers one annual cycle with a fairly complete set of atmospheric, lower boundary (land, ocean-ice) surface, and upper boundary radiation budget measurements. Model studies are to be applied to simulation of the annual cycle, examining the morphology of seasonal progression. These include studies of interactions among tropical, subtropical, and midlatitude circulations; cross-hemispheric couplings; seasonal surface moisture and albedo changes; cloud-radiation dynamics; midlatitude ocean moderation of atmospheric seasonal cycles; and ocean-atmosphere coupling and general circulation model sensitivity to equatorial oceanic conditions.

- **Establishment of potential limits of climatic predictability and identifying those climatic variables that are most predictable** (NSF, NOAA, NASA).

  Systematic studies will be directed at establishing lower and upper limits of predictability for short-term climate fluctuations. Included, in addition to theoretical studies, are tests of empirical forecasting techniques and measurements of the "climatic signal" as a fraction of total variability. Predictability as a function of location and comprehensiveness will be investigated, and the degree to which climate variations are related to measurable boundary conditions will be explored.

- **Improvement of statistical techniques of climate prediction** (NOAA, NSF).

  Successes toward this objective will assist directly service-oriented groups (e.g.,the NOAA Climate Analysis Center) that currently rely upon empirical techniques for operational forecasting. As a Principal Thrust of the Program, added steps will be taken to ensure further development of prediction tools and techniques and compatibility with operational methods.

- **Improvement of dynamical prediction tools** (NSF, NOAA).

  General circulation models (GCM's) and some simplified climate models are now sufficiently developed that they can be tested systematically for predictive skill. GCM's will be applied first to monthly and seasonal forecasts using observed initial data and projected boundary conditions. Some simplified models can be tested for longer term predictive skill, because of their more economical computing requirements. This task is viewed as a long-term investment to be carried out at perhaps two or three institutions. Direct involvement of the planned experimental forecast groups is envisaged.

3. Studies of physical climate processes

This activity probes the climate behavior documented by the observed or reconstructed climatic record. Special studies are to be supported to understand how elements of the climate system work and to refine key concepts of physical processes that form the bases for realistic climate models.

- **Improving understanding of heat storage and transport in the oceans and coupling with the atmosphere** (NSF, NOAA, DOD, NASA).

  Continuation of large-scale ocean process field programs will be supported to explore the relative roles of tropical, midlatitude, and polar oceanic features in contributing to atmospheric variability. Equatorial regions will be studied for monsoon responses, eastern and western boundary current effects, and mean current anomalies including the effect they may have on thermal anomalies. Emphasis of the Principal Thrust on Ocean Heat Transport and Storage is on the ocean contribution to the planetary meridional heat flux and the role of eddies in heat transport. NOAA and NSF will play the largest roles in this task, with both agencies seeking other agency, academic, and international participation.

- **Establishing the strengths of the sources, sinks, and transformations of low-concentration geochemical compounds suspected of having the potential to alter climate** (DOE, EPA, NASA, NSF, NOAA).

  Gases or compounds that could be produced in quantities sufficient to affect atmospheric heating or radiative properties will be studied. Of particular interest at this time are aerosols, carbon dioxide, chlorofluoromethanes, and nitrogen and sulfur oxides. Their sources and sinks in the atmosphere, the biota, on land, and in the ocean will be investigated. DOE is a major supporter of research in this area, having particular interest in the carbon cycle. NOAA and NSF involvement is broad-based, extending from measurement strategy to analysis and modeling of geochemical characteristics. The NASA interest concentrates on stratospheric gases. The EPA studies seek to understand industrial, agricultural, and urban growth effects on tropospheric concentrations of suspect trace compounds.

- **Examining climatic processes important to understanding feedback mechanisms and phenomenology of atmospheric dynamics** (NOAA, NASA, NSF).

  Observational studies will be made of albedo and moisture variations, atmospheric dynamics and energetics, quasi-stationary atmospheric wave development, cloud and aerosol-radiation dynamic interactions, geographical thermal forcing, global radiation budget features, land-surface factors, monsoon formation mechanisms, and sea-ice dynamics. Field observations will be backed by mathematical and laboratory modeling experiments.

- **Examining the Earth's radiation budget and exploring the mechanisms by which solar variability may influence climate** (NASA, NOAA, NSF, DOD).

  The quantity and quality of solar radiation and its variation as a factor in affecting climate will be examined, particularly with respect to

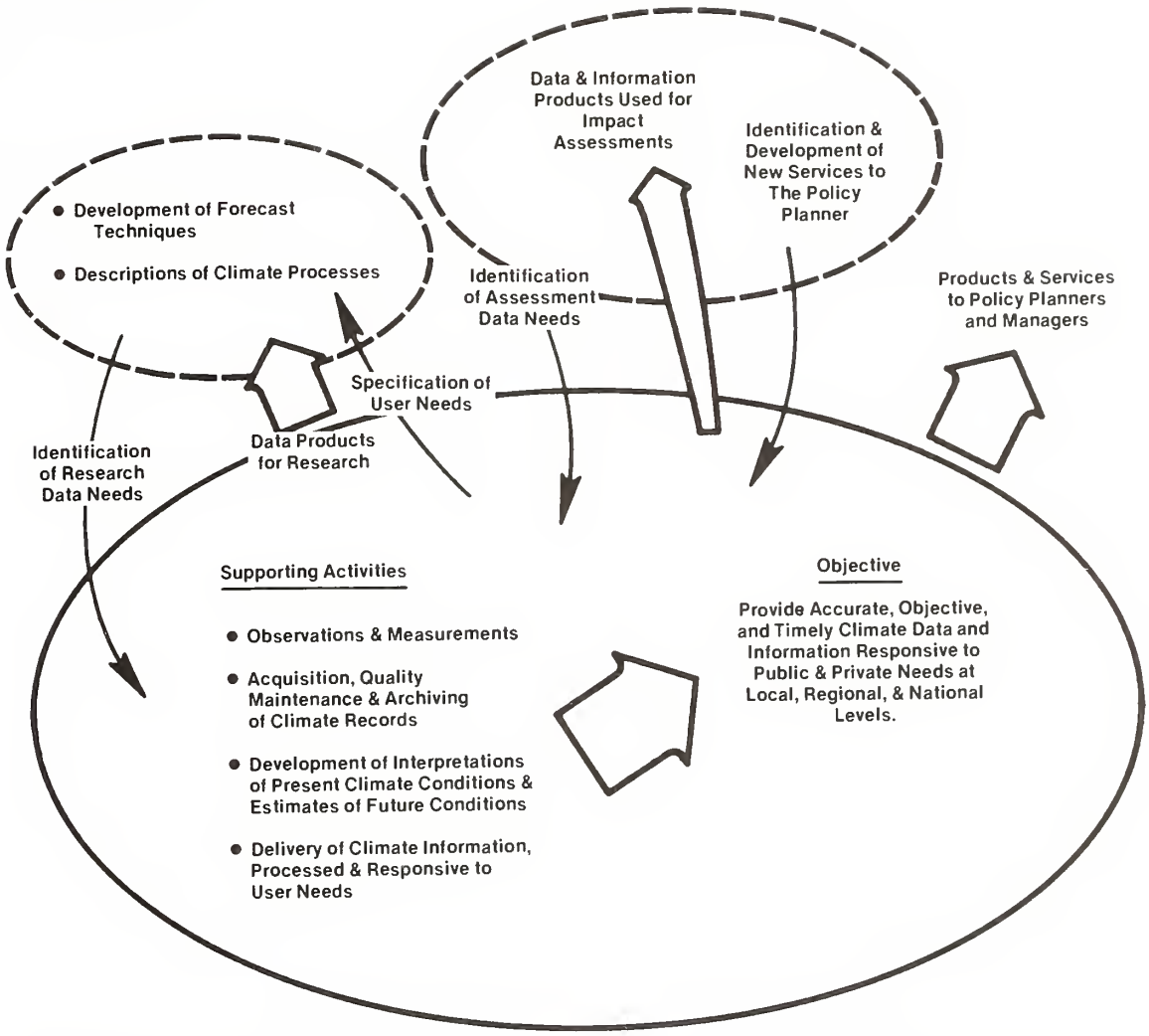

Figure 6.—The Climate Data, Information, and Services component and its relationships to the other Program components.

upper atmosphere responses to changes in solar flux and corresponding mechanisms for connections through the atmosphere. Studies are required to determine cloud-radiation dynamic interactions, atmospheric transmissivity, and aerosol and trace gas distributions and their radiative properties. Research will be encouraged to determine the effects of changes in land use, vegetation, and snow/ice cover; and to define the physical, dynamical, and radiative characteristics of major stratiform cloud systems and their extra-area environment.

C. Data, Information, and Services

The Data, Information, and Services component of the Program seeks to provide accurate and timely data and information products responsive to public and private sector needs.

Transmission and management of information on climate are essential to allow research and assessment (fig. 6). Data acquired for research and assessment must be accessible to users.

The four supporting activities for this component are: (1) Observations (i.e., Monitoring), to record the characteristics of the climate system; (2) Data Management, to acquire, maintain the quality, and archive data related to the climate system's behavior (which often includes compilation of supporting data not necessarily derived from the Observations activity); (3) Analysis and Prediction, to use current data, the historical record, and sophisticated analytical techniques to extract information on climate behavior and to estimate future climate conditions; and (4) Information Services, to deliver climate information responsive to user needs.

Most aspects of these supporting activities are well developed and conducted on a continuing basis. In principle, the sequence of information flow is from basic measurements, through data management, analysis and prediction,

Table 7.—Climate variables

Atmospheric structure	**Snow and ice**
Winds	Sea ice
Temperature	Snow- and ice-covered terrain
Humidity	Ice discharge
Pressure	Changes in area and elevation of polar ice sheets
Precipitation	
Cloudiness	
Oceanic variables	**Hydrological parameters**
Sea-surface temperature	Precipitation
Wind stress	Soil moisture
Sub-surface temperature structure	Evapotranspiration
Salinity/density structure	Ground water
Near-surface currents	
Deep ocean circulation	**Atmospheric composition**
Solar and Earth radiation	Water vapor
Solar constant	Carbon dioxide
Solar spectral irradiance	Ozone distribution
Earth-reflected solar (albedo)	Aerosols
Earth-emitted infrared	Other trace gases

and out to the user through various information services. However, users often need both raw data and processed analyses. So within each function, attention is given to the direct users as well as to the next step in the normal flow of information.

1. Observations

The climate system involves complex and subtle interactions among many environmental components. It is necessary to acquire accurate records in order to discern relationships, develop theories, and extract and apply useful information.

Climate observations must be made globally and, for the most part, over long periods of time. They include, moreover, a large number and variety of variables (table 7). All observational requirements of the Climate Program cannot be met at this time. Deficiencies involve accuracy, sampling, and coverage.

All systematic measurements required for monitoring variations of the climate system, as well as the potential sources of variations, are included in the observation activities of the Program. Climate System Research includes many specialized observing activities, integral to studies of climate processes. In general, if the effort requires continuity over a long period of time (as opposed to the life of an individual research project), or if the effort is clearly intended to be a precursor of an operational measurement program, then it will be included programmatically under Data, Information, and Services, even if the primary users of the data are in the research community. Monitoring solar radiation and the Earth's radiation budget fall into this category.

The climate data and information system begins, in most cases, with observations made primarily to support weather operations. All weather data are potentially climatological data. There are, however, two essential differences: processing and quality control. Weather data soon lose their usefulness, but climate data become more valuable with time. For weather purposes one usually seeks to measure relatively large differences, and gradual drifts of instrument calibrations can be tolerated, recognized after a while, and corrected eventually. For climate purposes, observations made at widely separated times and places must be comparable, and calibration drifts cannot be tolerated.

Observing programs must range from local (covering oceans as well as land), sometimes relatively unsophisticated measurements, to global satellite experiments that may be at the frontier of advanced technology. Research, international negotiations, and careful attention to costs and benefits are necessary to improve these observations.

The plan for Climate Observations is to expand existing capabilities and develop operational and research observing systems in accordance with total program requirements. This includes improvements to existing, surface-based *in situ* measurement systems and operational remote-sensing satellites, and the development of new instruments, platforms, and sensor techniques.

In striving for an effective and efficient climate observing system, strong international participation is essential. To this end, many observational methods developed for the GARP Global Weather Experiment (e.g., drifting ocean buoys, aircraft wind data) will be continued, and U.S. participation in the World Climate Program will be encouraged.

Observations activities are classified in five categories:

- **Atmospheric structure** (Principal agencies involved: NOAA, FAA, DOD, NASA).

  Atmospheric variables (temperature, winds, humidity) are the common aspects of climate that we all experience. Measurements made by NWS and FAA for short-term weather forecasting are the major source of these data. However, meteorological monitoring systems at times fall short of climate needs, as to both fine-scale data for local services and large-scale data sets suitable for global climate interpretation.

  NOAA operates two surface climate measurement networks: the Reference Climatological Network, currently 21 stations, which make long-term, high quality, baseline measurements, and the Cooperative Observer Network of about 8,000 stations to provide local-scale data. In addition to these networks, local-scale data are collected by many Federal, State, and local governments and by private parties.

  Climate research and applications require the accuracy and comparability of measurements over relatively long periods of time. These are more stringent requirements than those on data used to support short-term forecasts. Efforts will be made to assure comparability among measurements from different sources and from

different generations of sensors. For applications use, most data are likely to come from the basic ground station network. Thus, there will be an effort to upgrade station inspection programs, including NWS, U.S. Forest Service, and USGS activities, and to agree upon standards and measurement techniques. On a larger scale, steps will be taken to continue certain monitoring operations in the Southern Hemisphere begun under the Global Weather Experiment.

- **Oceanic observations** (DOD, NOAA, NASA).

  Historically, ocean observational methods have had to rely upon ships, drifting buoys, and fixed stations. Because of the vast areas involved and the severity of the environment, it has not been possible to have adequate, comprehensive coverage at reasonable cost.

  Satellites promise to provide much of the comprehensive, global coverage that is needed of sea-surface conditions. The short-lived SEASAT carried experimental instruments to give information on sea-surface temperature, wind stress, topography, and wave dynamics. The National Ocean Satellite System will provide even better climate observing capabilities.

  Nevertheless, *in situ* measurements of surface and subsurface conditions such as currents, temperature profiles, and salinity gradients, unobtainable from satellites, will be developed to satisfy climate requirements. Satellite measurements of surface characteristics must in any case be verified. Long-term observations of surface and subsurface characteristics using a mix of ocean observing platforms need to be continued. One of the most exciting developments of the Global Weather Experiment has been the emergence of drifting buoys, communicating *via* satellite, as an effective system for obtaining marine data.

  The National Climate Program Office is sponsoring a study to devise a strategy for achieving an optimum ocean climate monitoring system that can be realized on a gradual basis over the next two decades (shown in fig. 7). This study, being made by the University Corporation for Atmospheric Research, will provide advice on which emerging technical developments and which type of current technology should be pursued most vigorously.

  The present ship-of-opportunity program (supported largely by DOD, NSF, NOAA, and the

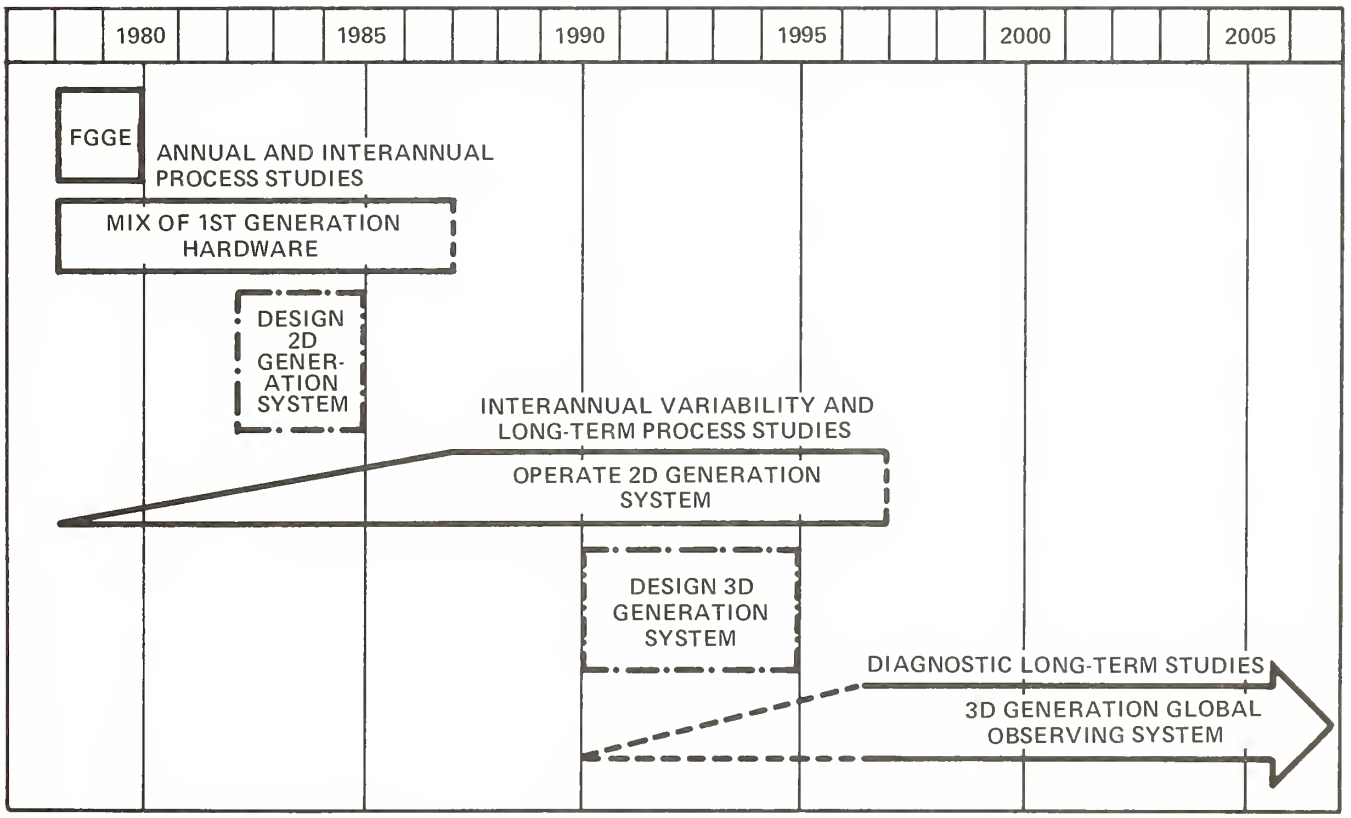

Figure 7.—Phased development of ocean climate monitoring capabilities, based on suggestions of the U.S. GARP Committee (1978).

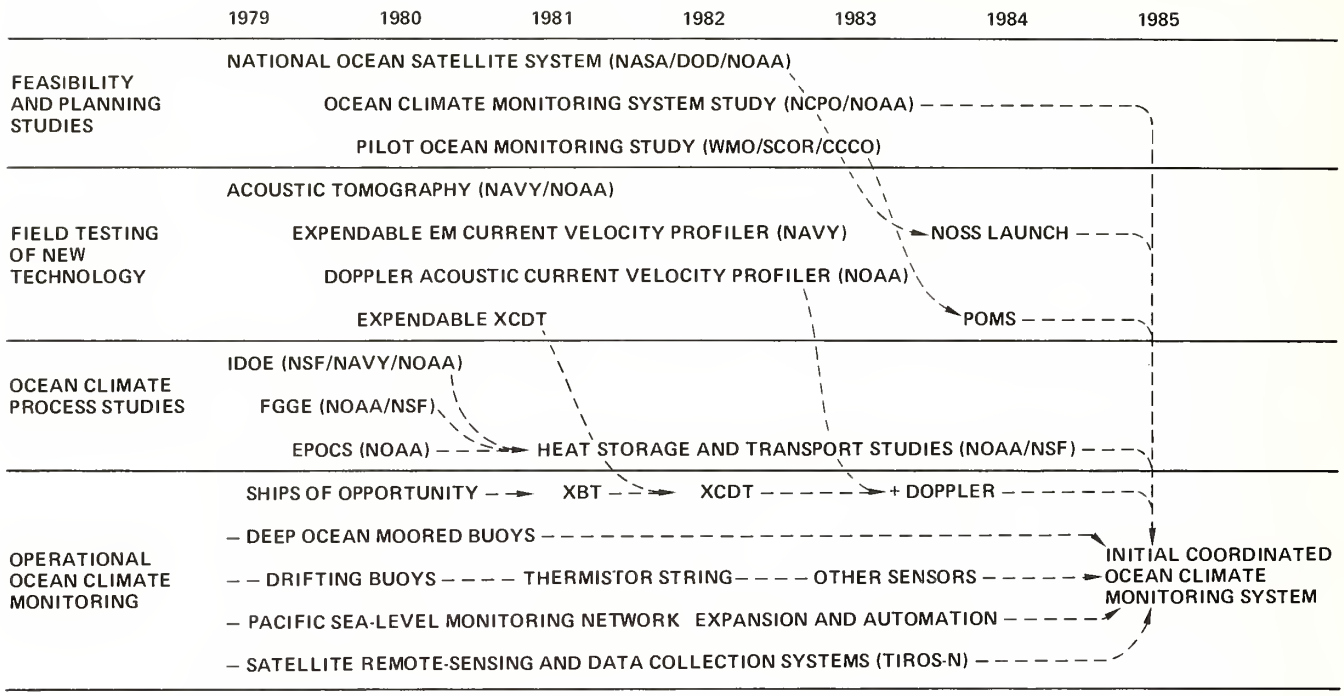

Figure 8.—Contributions of various projects to the evolution of an operational global ocean monitoring system.

U.S. Coast Guard) and the international Integrated Global Ocean Station System (IGOSS) program are important sources of ocean data. The NOAA tide gage network (as a source of sea-level data) will be maintained as an important part of the total observation effort.

The research programs discussed earlier will supply important parts of the needed observational data over the next decade. Wherever possible, promising new techniques—such as acoustic tomography, electric field recording, and Doppler acoustic current profiling—will be field tested in conjunction with these research programs for purposes of strengthening the scientific effort and speeding the development of an operational global ocean monitoring system (fig. 8).

- **Precipitation and hydrology** (NOAA, DOI, USDA, NASA).

Precipitation is particularly difficult to measure. It varies greatly in both time and space, and individual rain gages are poor indicators of integrated precipitation. Many gages, however, can be averaged to give acceptable estimates. Thus, the U.S. observing network (about 11,600 stations) is important to maintain.

A means of acquiring a uniformly consistent representation of global precipitation for all areas (ocean and land) is fundamental to determining the natural variability of climate and establishing and verifying climate forecast models. Space-based remote sensing is desired, because most of the globe is covered by oceans where adequate surface-based rainfall measurements are not feasible. The Climate Program will pursue global measurement capabilities, first following the promising results obtained by NOAA and NASA in extracting precipitation information from satellite-borne microwave, infrared, and visible radiometers. Satellites will be used also to relay data taken by automated surface-based stations

- **Snow and ice measurements.**

Year-by-year and decade-by-decade variations in polar ice conditions seem to be large, and the extent of ice and snow appears to be a significant factor in the dynamics of climate. Polar-orbiting satellites obtain visible wavelength pictures of ice and snow cover in clear, sunlit areas. Microwave measurements have lower spatial resolution, but yield similar information through clouds and during long, dark polar winter periods. Studies to improve satellite measurement interpretation of these and other snow and ice parameters (e.g., ice age and thickness) will be urged through the Climate Program. Large continental ice sheets and associated glaciers, records of which are very limited, also warrant long-

term monitoring. Both *in situ* and remote sensing measurements will be encouraged.

- **Solar-Earth radiation and atmospheric composition.**

  A very high priority requirement in climate research is continuing, careful measurements of the Earth's radiation budget. Such measurements must include solar incident and reflected irradiance as well as emitted terrestrial radiation and information on cloudiness and variation in atmospheric composition.

  Earth radiation budget data are now derived from infrared scanning radiometers aboard NOAA's operational polar-orbiting satellites. These data are of limited value because of spectral and orbital constraints, instrument inaccuracies, and uncertainties regarding the variability in time and space of radiatively active constituents of the atmosphere. Additional data are collected from NASA's NIMBUS-G experimental mission. NASA and NOAA are planning a coordinated series of satellite measurements—the Earth Radiation Budget Experiment (ERBE), Stratospheric Aerosol and Gas Experiment II (SAGE II), and Halogen Occultation Experiment—for the specific purpose of obtaining solar and terrestrial radiation measurements and related measurements of radiatively important atmospheric constituents. The ERBE instruments will be included in NOAA-F and -G polar-orbiting satellites in 1984 and 1985, respectively. In the meantime, NOAA is developing techniques to derive radiation budget measurements from geostationary satellites to supplement polar-orbiting satellite data.

  The NOAA Geophysical Monitoring for Climate Change (GMCC) Program operates a network of stations for observing solar radiation and radiatively important atmospheric constituents. The network includes 4 baseline observatories (Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and the South Pole), 7 regional total-ozone monitoring stations, and 10 regional stations monitoring atmospheric turbidity.

  NOAA and DOE operate ground-based stations to measure direct and diffuse solar radiation, complementary to the various satellite programs. Endorsed by the Climate Program, both types of measurements are being developed to assure continuity over at least two decades, and extended to detect variations in the solar spectrum, especially in the ultraviolet.

2. Data management

Management of data is difficult because of the volume of data available. Data not saved, or saved but inaccessible, are lost. For example, if they are saved and accessible, but of unknown quality, or too costly to obtain, then the value of the costly observing systems by which they were obtained must be doubted. The entire data management process must be responsive to those who would use the data—a varied group, with widely differing requirements.

As shown in figures 3, 5, and 6, a key effort in Data Management will be the preparation and dissemination of high-quality data sets to support other Climate Program components. Supported activities will provide an inventory of national and international data bases and increase convenient, timely access to the data. Studies, analyses, and compilation of useful indices of climatic behavior are also needed by the companion Program components to improve forecast capabilities, to support various assessment projects, to provide timely information on evolving climatic extremes, and to support research on climate processes.

Data management activities may be divided into two principal, continuing functions: (1) Preparation of Data Sets—aggregations of data processed to facilitate analyses; and (2) Maintenance and Improvement of the Data Management System—provision of basic archival services and continual upgrading of the capability to meet user needs effectively for timely, comprehensive, high-quality data. Activities to prepare and make accessible certain high-priority data sets include:

- Extending compiled **surface temperature, precipitation,** and **snow** data to 10-year periods (where available) to support crop yield assessments, crop modeling, and fuel demand modeling.
- Preparing an inclusive set of **surface data from ships-at-sea;** assembling selected **tide data.**
- Completing preparation of U.S. surface-based, **solar radiation data** (from 1951 onward), adding **ultraviolet data** where available; completing preparation of older **CO_2 data sets.**
- Compilating **experimental satellite data on radiation, trace gases, and other climate parameters.** These sets include radiance measurements relating to the heat budget, ozone and other trace gases in the stratosphere, rainfall derived from cloud temperatures and from microwave emittances, polar ice boundaries, sea-surface temperatures, and winds. NASA intends to apply proven analytical and managerial techniques to the compilation of additional satellite data sets.

An increase in activity in other areas of the Climate Program will produce new demands for data services. Among these demands we anticipate increased requirements for paleoclimate data, and impact assessment studies will require preparation of selected specialized data sets that will include topographic, land use, and soil and vegetation characteristics.

The data management system provides basic archival services to the user. The many types of data, the various sources, and the need for assimilating different types of data all motivate the need to tie data management together.

Gathering and preparing past data into high-quality, coordinated sets are large efforts, but the many U.S. and foreign agencies make it tractable. An interagency effort is underway to complete and to keep current an inventory of climate data. Available modern data communication technologies will be tested. These include computer "dial-up" to query data bases and automated collection, processing, storage, and dissemination of data.

3. Analysis and prediction

The analysis and prediction activity is an important information output element of the National Program. The Nation's ability to "understand and respond" to climate fluctuation depends heavily on the availability of timely, accurate, reliable information on those variations. Information on climate is generally of three types:

- **Current information** on contemporary climate conditions in the context of the climate record (e.g., precipitation to date compared to the historic record of annual precipitation up to that date). Such information requires rapid reduction, analysis, and interpretation of large amounts of weather and climate data.
- **Forecasts** of climate conditions, say, for durations of weeks, months, or seasons with appropriate lead times. Such information is widely sought and of great value, but present capabilities are limited.
- **Statistical estimates** of climate parameters based on analysis of the climate data record.

The NOAA Climate Analysis Center (CAC) provides both current climate awareness and climate condition forecasts. This is part of NOAA's overall civil sector responsibility to provide general climate information. CAC also publishes climate conditions related to agriculture (e.g., the Weather and Crop Bulletin in cooperation with USDA). NOAA will support the following continuing functions:

- Data analysis, interpretation, and provision of current climate information.
- Publication of monthly and seasonal climate outlooks.
- Provision of diagnostic data for research on climate anomalies.
- Improvement in forecasts—in accuracy, lead time, and information content—including support of non-Federal research to improve forecasts.

In addition to NOAA's monthly and seasonal outlooks, the Department of Agriculture makes forecasts (up to seasonal duration) of snow melt run-off to aid in watershed management and irrigation allocations.

As potentially valuable as general climatic forecast information may be, it is currently limited in reliability and information content. The most useful climate information continues to come from statistical analysis of the climate record.

4. Information services

A clear intent of the National Climate Program Act was to stimulate more effective dissemination and use of climate information to conserve natural resources, increase industrial and agricultural productivity, and contribute to sound policy decision in both public and private sectors. The use of climate information is the ultimate payoff of the Climate Program. Major Federal capabilities in applied climatology are at the NOAA data centers (e.g., the National Climatic Center) and in DOD at the USAF Environmental Technical Applications Center and the Fleet Numerical Oceanography Center. Both DOD and NOAA data centers support gobal applied climatological operations.

State Climatologists and private consulting climatologists also provide many important applied climatological services, and their role, nationally, will increase as the Principal Thrust in Information Generation and Dissemination is pursued.

Wider, more effective use of climate information is the aim of the Information Services activity. Its continuing functions are to:

- **Evaluate existing services and establish priorities to address unmet user needs.** This task involves outreach to users—particularly through representative user groups and intermediary suppliers such as State Climatologists and private consultants. These groups will be reached through workshops, user conferences, and technical society meetings.
- **Develop new or improved climate information products.** As critical problems and requirements change, it is essential to derive parameters most beneficial to all potential users and to compile the needed data base. This development of new climate information products, responsive to users' needs, is a key, critically important area of applied climatology. It requires and will receive a great deal of attention.
- **Deliver climate information and provide user education.** More effective, decentralized delivery techniques are being developed (see Principal Thrust on Information Generation and Dissemination) to speed the flow of climate information and facilitate its application. Professionals at the local level will be able to consolidate data from several sources and assist in their interpretation and application. State Climatologists will, in some degree, approximate the military system of staff weather officers who connect field commanders with centralized climatological services.
- **Evaluate and document the benefits of wider use of climate information services.** It is important for planning information system designs that the approaches found most effective in treating particular problems are replicated. Documenting specific techniques and their benefits enable the transfer of capabilities and encourage even wider use of successful techniques.

PART III

IMPLEMENTATION OF THE NATIONAL CLIMATE PROGRAM

CHAPTER VII

SPECIAL ASPECTS OF THE PROGRAM

A. International Activities

The Congress, in enacting the National Climate Program Act, found that

> ". . . Climate fluctuations and change occur on a global basis and deficiencies exist in the system for monitoring global climate changes. International cooperation for the purpose of sharing the benefits and costs of a global effort to understand climate is essential . . ." (Sec.2(5)).

Thus, the Congress said, the purpose of the National Climate Program is to "assist the Nation and the world" to understand and respond to climate (Sec. 3).

Each of the priorities established in this first Plan for the National Climate Program builds upon international programs and needs. International activities that are integral to the Principal Thrusts of the National Program are illustrated by the milestones in table 8, a subset of those that appear in Chapters III, IV, and V. In addition, international efforts are explicit in many of the Areas of Program Concern, as for example Semiarid and Arid Lands, and Air-Sea Interaction.

Table 8.—Selected milestones of principal thrusts

Priority Area	Milestone	Fiscal Year
Generation and Dissemination of Climate Information	Sponsor, with WMO, Planning Conference on Climate Data Inventories and Information System	1982
	Initiate international climate information and inventory system development project	1983
Climate Prediction	Participate in international evaluation of progress on prediction techniques development	1984
Carbon Dioxide, Environment, and Society	Make biomass measurement field test in tropical forest	1981
	Hold major international workshop on global carbon cycle	1982
Solar and Earth Radiation	Begin development of Global Cloud Data Set as a program under the aegis of the World Climate Research Program	1981
Ocean Heat Transport and Storage	Hold Planning Conference to develop U.S. ocean heat flux proposal for international consideration	1980

1. Importance to the National Program

The National Climate Program Act requires that the Program include "measures for increasing international activities" (Section 5(d)(6)). Coordinated efforts to foster international cooperation are required. Specific requirements are as follows:

> "(1) The Program shall be conducted so as to encourage cooperation with, and participation in the Program by, other organizations or agencies involved in related activities. For this purpose the Secretary shall cooperate and participate with other Federal agencies, and foreign, international, and domestic organizations and agencies involved in international or domestic climate-related programs.
>
> (2) The Secretary and the Secretary of State shall cooperate in (A) providing representation at climate-related international meetings and conferences in which the United States participates, and (B) coordinating the activities of the Program with the climate programs of other nations and international agencies and organizations, including the World Meteorological Organization, the International Council of Scientific Unions, the United Nations Environmental Program, the United Nations Educational, Scientific, and Cultural Organization, the World Health Organization, and Food and Agriculture Organization."—Section 5(f)

These mandates give formal recognition to the unique international nature of climate. Climate is globally interconnected even though its impacts are more often felt on local and regional scales. International cooperation is essential in collecting and disseminating climate data, undertaking the necessary climate research, and assessing climate impacts. The United States cannot manage this task alone. It must take advantage of the scientific knowledge and financial resources of other nations and international bodies.

Regional and global climatic events, whether caused by nature or by man, have a major impact on food supply, water resources, and the use of energy in individual countries. The events have economic and political consequences and often raise significant foreign policy issues and humanitarian concerns.

Of special importance is the vulnerability of many developing countries to climate variability. Many of these nations' economic and social structures are based on agriculture. They often do not have the resources, the technical skill, or the knowledge to mitigate the impact of climate fluctuations. Hundreds of millions of people live on a narrow

margin of subsistence. Adverse climatic conditions may threaten their ability to survive. It is in our national interest—and in the world's—to help the developing countries understand and deal with potential climate change.

Of course, the United States, despite its great productivity and advanced socioeconomic infrastructure, is not impervious to climate variations. As a major consumer of global resources and a major source of pollutants that may affect climate, the United States has special responsibilities. It has an obligation to promote international cooperation on climate issues, to exhibit sensitivity to the problems of other nations, and to encourage other nations to consider and analyze climate and its effects.

2. The World Climate Program

In February 1979, participants from more than 50 nations met at the World Climate Conference. They urged all nations and international bodies to support a new World Climate Program. Subsequent action at the Eighth World Meteorological Organization (WMO) Congress, supported by decisions of the International Council of Scientific Unions (ICSU) General Assembly, the United Nations Environment Program (UNEP) Governing Board, and most recently the Intergovernmental Oceanographic Commission (IOC) General Assembly, has established the Program on a formal basis. It requires, deserves, and will receive full support from the United States.

The World Climate Program will complement and further the objectives of the National Climate Program. The National Program should aid in the structure and design of the World Climate Program so that both the World and the National Programs can succeed.

The World Climate Program comprises four sets of activity (or subprograms): a World Climate Research Program, a World Climate Impact Studies Program, a World Climate Applications Program, and a World Climate Data Program.

Overall coordination of the World Climate Program rests with WMO. Implementation plans are being developed now. Coordination will be discussed at the WMO's newly created Scientific and Technical Advisory Committee, which will meet for the first time in early 1980, and tentative plans exist for an intergovernmental organizing meeting later in the year.

The World Climate Research Program, guided by a Joint Scientific Committee (JSC) that is named jointly by WMO and ICSU, will be the focus of international climate research efforts. Table 9 gives the initial membership of JSC. Its structure is almost identical to that of the WMO/ICSU Joint Organizing Committee, which so successfully planned and organized the Global Atmospheric Research Program. JSC will build on the GARP experience, modify some objectives and disciplinary foundations, create some new institutional relationships, and proceed to plan and organize a program. For example, ties with the Committee on Climate Change and the Ocean (CCCO), which is sponsored by the ICSU Special Committee in Ocean Research (SCOR) and IOC (UNESCO), are being established. Joint sponsorship of CCCO by IOC, an intergovernmental organization within the United Nations' structure, and by SCOR, an international nongovernmental body, follows a pattern that has been very successful in the organization of the Global Atmospheric Research Program.

Table 9.—WMO/ICSU Joint Scientific Committee initial membership (1/1/80)

H.-J. Bolle (Austria)	C. Lorius (France)
K. Gambo (Japan)	A. M. Oboukhov (U.S.S.R.)
E. O. Holopainen (Finland)	M. A. Petrossiants (U.S.S.R.)
J. T. Houghton (U.K.)	J. Smagorinsky (U.S.A.)
D. Lal (India)	G. B. Tucker (Australia)
C. E. Lieth (U.S.A.)	J. D. Woods (F.R.G.)

The **World Climate Data Program** and the **World Climate Applications Program** are responsibilities of WMO. A management structure for these subprograms has not yet been developed.

The World Climate Impact Studies Program is the responsibility of UNEP, which is developing an action plan for submission in 1980 to the eighth session of its Governing Council. We expect that this plan will integrate the capabilities of international and national governmental and nongovernmental organizations.

3. Interface between the National and the World Climate Programs

As table 8 indicates, the National Program includes numerous international activities as essential to the success of the National Program. These activities will be presented or sponsored by the National Program.

A special emphasis of the World Climate Research Program will be ocean climate research, involving international experiments to study ocean heat transport and storage and perhaps culminating in the next decade in a Global Ocean Circulation Experiment. A specific U.S. proposal for such undertakings is being developed.

Appropriate National Academy of Sciences groups, under the general guidance of the Climate Research Board, will recommend special proposals connected with each of the National Climate Program's research-oriented Principal Thrusts and Areas of Concern appropriate to the World Research Program. Suggestions or recommendations for special, internationally coordinated efforts will be developed and presented to the National Climate Program Policy Board for possible inclusion in the National Program.

Activities included within the framework of the World Climate Research Program will be part of the National Program, funded among the climate activities of the various agencies. Climate System Research related to the World Climate Research Program will be coordinated by the U.S. GARP Office in NOAA. The extent of U.S. support for technical and scentific exchanges in connection with

the World Climate Research Program will be noted in National Program Annual Reports as an accomplishment.

Special efforts will be needed to assist the developing countries to become involved fully in the World Climate Program (WCP), to contribute to it, and to benefit from it. Resources for such assistance can come from the United Nations Development Fund, specialized U.N. agencies, and national contributions. The United States can provide some direct assistance in special situations through the Agency for International Development, through its contribution to the WMO Voluntary Contribution Program, or through certain agency programs. Additional planning and experience with the WCP will be needed to judge the adequacy of present assistance programs and resources, and the need to propose new arrangements.

Climate prediction capabilities are being developed and tested in several countries. The United States will work with WMO in an international review of the status of climate prediction, beginning in 1981, and culminating in an international symposium in 1982. One purpose of this effort will be to establish the basis for international distribution, through the World Weather Watch communications channels, of global and regional climate forecasts and accompanying statements, according to accepted standards, of skill or reliability.

The Climate Data Inventory System described in this Plan is an essential step toward making climate data accessible to those who require it. Development of an international data referral and exchange system is possible, based on present WMO and IOC cataloging of atmospheric and marine data. The United States will participate actively in promoting this activity within the framework of the Principal Thrust in Generation and Dissemination of Climate Information.

Observing systems are essential to record climatic events. The United States is developing plans, in conjunction with other nations and WMO, for the operational implementation of some of the observing systems that proved so successful in the Global Weather Experiment. The routine transmission of weather data, *via* satellite, from commercial aircraft and from drifting buoys will provide a continuing improved data base for weather forecasting and climate analyses. The buoy program is particularly significant as an adjunct to scarce data on marine climate.

CO_2 studies will involve analyses of regional and global impacts of climate changes and/or responses to such changes. The U.S. will support studies in U.S. institutions, and will also provide partial support for similar efforts in developing countries. This collaborative effort should be guided by a United Nations Environment Program-supported steering group, with participation from ICSU within the framework of the Impact Studies stream of the World Climate Program. Funding would involve a combination of UNEP support, national support, and private foundation support.

Understanding of biogeochemical cycles, especially with regard to the carbon cycle, will be fostered by an internationally coordinated effort. The Scientific Committee on Problems of the Environment (SCOPE) of ICSU has been promoting a interdisciplinary approach, which the U.S. National CO_2 and Climate Program will support. Appropriate institutional ties must be established. UNEP, as an intergovernmental body responsible for assessing the state of the environment, will be urged to bring together national commitments to the effort. Suitable linkages are to be made between this effort and the SCOR/IOC Committee on Climate Change and the Oceans, activities examining the ocean's role in the carbon cycle; and also with the WMO/ICSU Joint Scientific Committee, which is the principal planning body for the World Climate Research Progam.

A **global monitoring plan** for detecting the early climatic effects of increased atmospheric carbon dioxide must be developed and implemented promptly. A specific charge to design such a monitoring plan should be directed to the WMO/ICSU JSC, which would coordinate closely with the WMO Project on Research and Monitoring of Atmospheric Carbon Dioxide, and also the Global Environmental Monitoring System (GEMS) program of UNEP. Implementation of such a monitoring effort would be under the aegis of WMO. UNEP would provide regular assessments of evidence for climatic effects as a component of its environmental assessment program. The United States will offer key scientific and computational assistance in the global monitoring design.

A joint international response to increasing CO_2 may be required. A respected international body of experts could help consolidate world opinion by examining and reporting on what is known, what obstacles remain, and what options suggest themselves. Such a body should not be just another planning or organizing body. Rather, it would make recommendations to international planning groups and nations on activities that should be stressed. The United States will work with other nations and international organizations to establish such a body, while simultaneously giving broad distribution to assessments and judgments of its own experts.

Regular assessments of the world food situation are a responsibility, internationally, of the U.N. Food and Agriculture Organization (FAO). The United States provides FAO with an assortment of agricultural and climatological data and information. Two aspects of international coordination warrant careful attention. First, there is need to develop, with UNEP, a clearly defined relationship between the FAO program and the World Climate Impact Studies stream of the WCP. There is also a need to investigate possibilities for funding for use in developing countries of information generated by FAO. U.S. experts can be made available to participate in these activities.

Desertification is often a transnational problem. The United States and Mexico, as neighbors whose boundary and adjacent regions include large arid and semiarid areas, have a strong mutual interest in measures to combat deserti-

fication. This has led to the initiation of a bilateral program. The United States can contribute initially to the bilateral program by development of a data base on the relevant climatological conditions in Texas, New Mexico, and Arizona for comparison and integration with historical data on land use and land management. This would allow regional perspectives and, in connection with similar Mexican activities, could serve as a data base for research on land and water management decisions in both countries. In addition, if sufficient interest exists in Mexico, the joint effort could be a pilot project exemplifying the type of activity to be promoted under the World Climate Data and Applications Program. A sequence of negotiations is necessary: first, with possible contractors to undertake the work in Texas, New Mexico, and Arizona; second, with Mexico, through the United States/Mexico Working Group on New Crops, Arid Lands, and Agricultural Productivity, to establish this activity formally as part of the protocol under the Bilateral Agreement; and third, with WMO with regard to the design and implementation of the applications and data subprograms of the WCP.

The United States, through the Agency for International Development, with participation by NOAA, has been contributing to the planning and management of climatological and hydrological facilities in the Sahel and in the Caribbean. The logical continuation of these activities would include developing data bases and applications guidelines. These, too, could be a pilot effort within the framework of the WMO subprograms.

The role of oceans in climate has been a matter of significant international scientific interest. These concerns are closely coupled to the U.S. National Program, and international developments in response must be encouraged. The United States (through NSF, NASA, and NOAA) is providing funds for a small secretariat for the SCOR/IOC CCCO. Initial IOC support for CCCO has been requested of UNESCO in its 1981-83 budget. The United States should support this UNESCO contribution and urge other nations to contribute. The United States should be willing to consider requests for support for travel or other costs associated with workshops or studies under CCCO aegis, but only if there are contributions from other countries to match the initial U.S. support.

A series of major international experiments related to ocean climate is being considered and warrants very careful planning. In particular, the United States should develop, in 1980, a specific plan for an international effort to study the ocean's role in the storage and transport of energy. Such international efforts in the North Atlantic would build upon activities connected with the Principal Thrust in Ocean Heat Transport and Storage of the U.S. National Program. The Ocean Sciences Board of the NAS/NRC will be asked to formulate such a plan for consideration and evaluation by NCPO, NSF, and other agencies, and for submission to CCCO and JSC.

One of the goals of such an ocean experiment, in approximately 1987, should be the testing, evaluation, and comparison of various evolving technologies for measuring large-scale ocean behavior. Satellite sensing of the ocean surface is one of those technologies. Japan, like the United States, has indicated tentative plans to launch oceanographic satellites. Early in the 1990's, these technologies may make possible a major international Global Ocean Circulation Experiment to obtain the first comprehensive view of the large-scale motions of the world ocean.

4. Special bilateral climate programs

U.S./U.S.S.R. joint activities. One of the areas covered by the U.S./U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection concerns the influence of environmental changes on climate. The responsible organizations for implementing this activity, designated as Working Group VIII, are NOAA for the United States and the State Committee for Hydrometeorology and Control of the Natural Environment for the Soviet Union. EPA is the responsible agency for U.S. participation in the overall agreement.

Working Group VIII, which provides a focus for applying the combined expertise of both nations, has fostered cooperation between the participating scientists and has produced exchanges of hitherto unavailable data. The U.S. participation in the program is shared broadly among scientists from Federal agencies, such as NASA, NOAA, and DOE, as well as from NCAR and the academic community. Soviet participation mainly involves scientists from the State Committee for Hydrometeorology and Control of the Natural Environment, but also includes scientists from the U.S.S.R. National Academy of Sciences and universities.

Activities conducted under the Working Group include short- and long-term visits to laboratories and universities, meetings and symposia, joint experiments, exchanges of climatic and paleoclimatic data, and comparisons of techniques and instruments for measuring atmospheric constitutents.

Planning for future cooperative efforts includes:

- The exchange of data and information on the climate of the Pleistocene and Holocene eras.
- Workshops on the climate effects of increased atmospheric carbon dioxide and the design and use of climate models for studying the carbon dioxide/climate relationship.
- Data exchange to expand the climate data base.
- Joint research on the effects of extended cloudiness on the Earth's heat budget.
- Investigation of the response of plants to changes in the concentration of atmospheric carbon dioxide.
- The development of joint experiments to study the effects of aerosols on climate.

- Intercomparison of techniques and instruments used in measuring chlorofluoromethanes and other gases affecting the atmosphere's radiative processes.
- Studies on the effects of solar variability on climate with emphasis on the physical mechanisms involved and the numerical modeling of atmospheric responses to these mechanisms.

Working Group VIII's program is to be conducted, wherever possible, in consonance with the activities of the U.S. and the U.S.S.R. National Climate Programs and the World Climate Program.

United States/China joint activities. In May 1979, the United States and the People's Republic of China signed an implementing agreement to promote collaboration and cooperation in atmospheric science and technology. Two specific activities under that agreement are climate monitoring and climate modeling. Efforts will be made to cooperate in climate monitoring by establishing and operating a climate monitoring station in China and by exchanging experts to visit monitoring facilities. There are also plans to assist Chinese experts in climate modeling by providing access to United States large-scale computers.

B. Intergovernmental Climate Program

1. Present State programs

The National Climate Program Act mandates that the National Climate Program provide "mechanisms for intergovernmental climate-related studies and services" (Section 5(d)(7)) and details establishment of intergovernmental climate programs for "Federal and State cooperative activities in climate studies and advisory services" (Section 6).

Many States have recognized already the need for local and regional programs to identify State climatological needs, study particular climate problems, and disseminate tailored climate information. These State activities vary in size and emphasis—usually in relation to the local climate, size of population, and the nature of the local economy.

Over the past 5 years, there have been active programs in at least 12 States—Arizona, California, Colorado, Illinois, Iowa, Michigan, Minnesota, New York, Oklahoma, Texas, Utah, and Wisconsin. Significant increases in the use of climate information have resulted. For example, the annual number of requests for climate information in Iowa reached 5,000 after only 2 years of program operation. The active programs serve multicounty planning groups; State agencies; Federal regional and field offices; agricultural, energy, water resources, and transportation interests; and the general public.

In addition to the most active State programs, most of the other States support minimally funded, part-time climate programs providing only limited climate information services. During 1979, New Mexico, North Carolina, Oregon, and Virginia took actions to upgrade their climate programs to full-time status.

Following enactment of the National Climate Program Act, the Director of the National Climate Program Office (NCPO) invited the Governor of each State to name an official representative to work with NCPO in developing the Intergovernmental Climate Program. As of July 1980, 46 Governors had named such a representative (Appendix III).

Federal responsibility for providing climatic data and information services is assigned to NOAA's Environmental Data and Information Service (EDIS). The EDIS facility carrying out most of the responsibility is the National Climatic Center (NCC) in Asheville, NC. NCC receives about 70,000 requests a year for climate information, and the requests are increasing at a rate of 4 to 7 percent per year.

The State Climatologists responsible for the local services have organized the American Association of State Climatologists (AASC) in order to exchange information and address technical problems of mutual concern. The current President of the AASC is the Illinois State Climatologist.

At present, NCC earmarks up to $25,000 annually to cover the cost of furnishing climatic data and information required by cooperating State Climatologists. The State Climatologists reciprocate by assisting in preparation of routine Federal releases and publications, and by handling hundreds of thousands of information requests annually that might otherwise be addressed to NCC or to National Weather Service Forecast Offices.

Illinois, Colorado, and most of the States now operating active, full-time climate programs have developed computerized local data archives. Indiana, Kentucky, and some other States are experimenting with modern communications and data processing facilities to allow them to provide services at low cost. Effective computer and communications access among States and with NCC is the goal for the mid-1980s and must be part of any intergovernmental program. Steps toward this end have begun. NCC is funding a pilot study with the Oklahoma State Climatologist to examine a small-system approach, evaluating its potential service- and cost-effectiveness. This pilot effort envisions early participation by a few other western States to determine problems of feasibility as a regional or national system.

2. Functions of the Intergovernmental Climate Program

The Intergovernmental Climate Program is to be a cooperative effort by the Federal government and the States. It is designed to achieve benefits from investments in climate research, studies, and services greater than those resulting from each governmental entity pursuing an independent course. Specifically, the functions of the cooperative effort are:

- To assemble, analyze, and make available local climate data of high quality.
- To inform sectors of the community about the importance of climatic impacts and the availability of data and methods of analysis.

- To assist States and local governments with climate-related issues.
- To identify needs for research and services.
- To focus and coordinate local and regional climate activities of diverse Federal agencies.
- To exchange and guide studies of climate impacts and demonstrate the value of climate services.

The Federal role is primarily one of assuring a structure exists so that these functions can be carried out. This Federal responsibility includes assuring an adequate source of data and basic information, and providing the support needed for specific local requirements of Federal agencies. The States determine the extent to which they will provide particular services.

3. Framework of the Intergovernmental Climate Program

The types of cooperative efforts needed can be divided into three categories: data acquisition and analysis, climate information services, and climate effects studies. Different formulas for partitioning costs between Federal and local sources may be needed for each category.

In **data acquisition and analysis** there may be several activities, now being carried out by the Federal government, for which responsibility should be transferred to competent State offices. For example, maintaining and improving surface climate data networks, an Area of Program Concern under Providing Climate Products, may be done more effectively at a lower cost through State participation. State offices might participate in assembling "Storm Data," a regular publication of the National Climatic Center. It is the basic source of authoritative data on severe and unusual weather, including damage and injury assessments. It is assembled on the basis of on-site interviews by local National Weather Service personnel. In recent years less time has been available for this activity and the proportion of recorded instances of severe weather (e.g., tornadoes), on which pertinent information is assembled, has fallen dramatically.

Other activities in this category are responsibilities of both Federal and State governments. They include monitoring the quality and reliability of local data sources, maintaining State inventories that can be integrated into the national clearinghouse activity, maintaining State archives, publishing summaries of State data, and aiding in the distribution of summaries produced by the National Climate Center. Not only are these activities essential to Federal responsibilities for generating and disseminating climate information, but also they are largely local responsibilities.

Most **climate information services,** the second category, will be primarily local responsibilities. These include advisory services, educational activities, and consultations with individuals and State and local government officials. These are to be supported largely by the States. On the other hand, information services provided to local offices of Federal agencies, and support of existing Federal extension and advisory services are Federal responsibilities.

Climate effects studies, the last category, are best judged on an individual basis. Those related to agricultural production, energy demand, or water resources planning are areas of major Federal concerns and statutory responsibilities. Support of activities in this category will be shared on a flexible basis.

4. Phased program development

The Intergovernmental Climate Program will be developed in phases. The first phase will consist of exploratory and exemplary projects to demonstrate the value of various modes of State/Federal cooperative climate activities, and to illustrate and test the different institutional forms that they can take.

Phase I is a crucial first step. Projects will be selected on the basis of their potential for:

- Providing necessary knowledge for the design and conduct of the National Climate Program through experience with local providers and users of climate information.
- Providing models of climatological services (whether provided by State, local or private organizations) that demonstrate quickly favorable benefit-to-cost ratios in relevant sectors of the economy, or that otherwise contribute to public well-being.
- Pointing to the potential markets for climatological services so that private climatological organizations will enter these sectors and create or expand self-sustaining businesses in cooperation with Federal, State, and local climatological entities.
- Demonstrating the value and effectiveness of intergovernmental processes in each activity category—data acquisition and analysis, climate information services, and climate effects studies.

On the basis of these projects decisions will be made as to the specific nature and schedule of subsequent phases. The evidence gained from these projects will be valuable to States and regions in supporting their evolving programs and to the National Climate Program in developing specific plans for further State/Federal cooperative activities.

The developmental phases of the Intergovernmental Climate Program will be managed by the National Climate Program Office. About $100K is available in FY 1980, and about $200K is planned for FY 1981. Estimates of the costs of subsequent phases of the program must depend on evaluation of these Phase I studies.

C. Experimental Climate Forecast Centers

The National Climate Program Act requires that the Program include

> "experimental climate forecast centers, which shall (A) be responsible for making and routinely updating experimental climate forecasts of a monthly, seasonal, annual, and longer nature, based on a variety of experimental techniques;

(B) establish procedures to have forecasts reviewed and their accuracy evaluated; and (C) protect against premature reliance on such experimental forecasts."

The National Climate Program contemplates designating such centers or groups as part of the Principal Thrust in Climate Prediction, one of the priority efforts in providing climate products. (See Chapter III.)

1. Purpose

The purpose of the experimental climate forecasting centers is to encourage the development and testing of innovative approaches to long-range prediction, and early recognition of capabilities. The experimental centers will not compete with operational climate prediction activities of the Climate Analysis Center. They are to provide to CAC a stream of well-tested approaches that can then be evaluated in an operational setting. Experimental centers will test, evaluate, and modify particular prediction techniques. Their concern will be the technical limitations of the methods, rather than operational constraints (such as timely availability of input data) or systematic production of predictions of known quality.

Several climate prediction development approaches are now being tried. Some are based entirely on empirical relationships: teleconnections, analogs, regressions. Some use physical relationships: air-sea interaction, solar influences, atmospheric tides. Others are founded on theoretical atmospheric dynamics. In the present early state of development of climate forecasting, none of these approaches is clearly superior. But there is no reason why combinations of these approaches might not be effective.

The experimental climate forecast program is intended to produce results in 5 to 19 years, developing and testing as broad a range of approaches as possible, and involving the scientists who have been most instrumental in developing the ideas. For longer range progress, reliance is placed on efforts in Climate System Research, particularly in development of climate simulation and prediction models. (See Chapter VI.)

The experimental climate forecast program will emphasize forecast verification—the development of measures to detect real rather than chance successes. Such verification activity is especially important in climate prediction, because of the relatively long time before the verifying event occurs and the relatively small number of replications possible in any period of time. Powerful verification tools are needed not only to distinguish the successful from the unsuccessful, but also to detect unsuspected skills which, although small, can lead investigators to improved forecast methods. The test designs themselves need to be statistically efficient enough to stand some chance of detecting success in a few years rather than a decade or more. This will require trying objective prediction methods on specially reserved collections of past cases, not just on slowly accumulating current cases.

The ultimate purpose of the forecasts is to provide useful information. Therefore, careful attention must be paid to how the results are presented. Among the criteria to be considered in selecting groups to participate in the program will be concern for the utility of the proposed forecast products, including such matters as format for presentation of the forecast, and the choice of which parameters are to be predicted.

2. Management

The experimental climate forecast center program will be administered by the National Climate Program Office, assisted by advisory groups and review panels.

Proposals for participation in the program will be solicited from non-Federal centers of climate expertise. Criteria for evaluating the proposals will include:

- Novelty and scientific soundness of the forecast approach(es).
- Understanding of the need for and difficulties of verification, and soundness of proposed test design and system for measuring skills and identifying improvements.
- Institutional setting of the forecast group—evidence of continuing successful climate research (as indication of continuing source of new ideas), and association with applied climatological activities (as stimulus to judicious selection of forecasted parameters, and development of insight into utility of predictions).

It is not possible to evaluate the success of this type of program after only 10 to 20 months. Therefore, initial, annual funding of an experimental forecast group will imply a commitment to multiyear funding. After 3 to 5 years, adequate evaluation of experimental centers will be feasible and some turnover will then be anticipated.

One of the legislative requirements is that centers "protect against premature reliance on . . . [their] forecasts." Proposals for participation in this program will have to recognize this caveat specifically. In general, experimental groups will be prohibited from initiating public releases or from calling press conferences to present timely experimental forecasts, and will be required to emphasize the experimental nature of the forecasts in all material that is released. Failure to adhere to such formally established guidelines will result in termination of funding.

3. Implementation schedule and funding

(See also discussion of options in Chapter I.)

Present plans call for the establishment of the first experimental climate forecast center in the last quarter of Fiscal Year 1980. The program option described in Chapter III, under the Principal Thrust of Climate Prediction, provides for the establishment of an additional group or two, assuming sufficient justification, later in the planning period.

In estimating program costs, the National Climate Program Office has assumed that each group would consist of the full-time equivalent of two to four professionals plus a

small supporting staff. In addition to personnel costs and associated overhead, the experimental groups may have significant expenses associated with computations and communications, depending on their forecast approach. This implies that each group would require support ranging between $0.2 and $0.5 million annually.

Groups, as they propose or develop their techniques, may identify requirements for climate data products or analyses that are not now available routinely. These will be produced, whenever possible, by the Climate Analysis Center, and some supplemental costs for this activity are anticipated. Finally, separate but related research grants pertaining to forecast verification and forecast utilization are needed to assist the groups.

About one-third of the support for the entire program would be directed to verification and forecast utilization studies.

CHAPTER VIII

ADMINISTRATION OF THE PROGRAM

The National Climate Program Act, Section 5(c), provides for the establishment of a National Climate Program Office (NCPO) which "shall be the lead entity responsible for administering the Program." The Act also describes other specific functions to be performed by various Executive Branch offices and agencies. For example: the 5-year plans are to be promulgated by the President (Sec. 5(b)(1)); the Office of Management and Budget is to review departmental requests for appropriations "as an integrated, coherent, multiagency request" (Sec.5(g)); the Secretary of Commerce is to establish and maintain a advisory committee who will "advise the Secretary and the Congress on the conduct of the Program" (Sec.5(e)); and the Secretary of Commerce is to submit to Congress an annual report which will contain "an analysis of the progress made toward achieving the goals and objectives of the Program" (Sec. 7(b)). Implied by these requirements are close interactions among the mission agencies in the development of Program activities. The Act, therefore, authorizes the Secretary of Commerce to establish and maintain interagency groups (Section 5(e)).

A. National Climate Program Office (NCPO)

NCPO has been established within the Office of the NOAA Administrator and is headed by a Director who reports to the Assistant Administrator for Policy and Planning.

The Office staff includes individuals from NOAA and individuals assigned to the Office from other agencies concerned with climate. The mix is about 50/50. Individuals from universities and non-Federal institutions participate in the Climate Program planning process via the Intergovernmental Personnel Act. This mode of staffing was established to reinforce the multiagency participation and program integration aims detailed in the Act.

NCPO has lead responsibilities for administering the Climate Program. To date, that has meant chiefly responsibility for planning, but other significant responsibilities include evaluating and reporting progress in meeting the Program's objectives, and providing support to the Office of Management and Budget with regard to agency budget requests. NCPO is also responsible for assuring coordination among the agencies participating in the Program. Several of the participating agencies (NSF, NASA, USDA, NOAA, DOI, DOE) have established agency Climate Program Offices, or their equivalents, to coordinate climate activities. These agency offices are the major points of contact with the National Program and NCPO.

In executing its functions, NCPO receives guidance and assistance principally from two sources: the National Climate Program Advisory Committee and the Climate Program Policy Board. These two groups are fully described below. NCPO is to provide these bodies, and others, with the necessary information and reports so that they can make suitable judgments, and to assess their advice and integrate it into Climate Program Plans and implementation.

B. Climate Program Policy Board and Interagency Working Group

The Climate Program Policy Board (CPPB) was established by the NOAA Administrator as the principal source of guidance to NCPO on all matters regarding the National Climate Program. It is the key link between NCPO and the other Federal agencies. The Chairperson is the NOAA Associate Administrator, the Executive Secretary is the NCPO Director, and CPPB members are policy level representatives of departments and agencies. Table 10 lists these departments and agencies.

The Board's specific functions are:

- Provide policy guidance for the Program, including relevant international activities.
- Review and approve all formal documents prepared by NCPO for the Congress, specifically 5-year Plans, annual reports, and recommendations for new legislation.
- Be a forum for discussion of major climate issues.

CPPB has sponsored an Interagency Climate Working Group, which meets more frequently than the Board itself. The Working Group provides the "informal system" necessary for the functioning of a program that crosses agency

Table 10.—Department and Agency Members of the Climate Program Policy Board

Department of Agriculture	Agency for International Development
Department of Commerce	Council on Environmental Quality
Department of Defense	Environmental Protection Agency
Department of Energy	Federal Emergency Management Agency
Department of Health and Human Services	National Aeronautics and Space Administration
Department of Housing and Urban Development	National Science Foundation
Department of the Interior	Office of Management and Budget (observer)
Department of Justice	Office of Science and Technology Policy (observer)
Department of State	
Department of Transportation	
Department of the Treasury	

lines and requires formal multiagency approval and implementation. In most cases the Working Group members are the heads of their agency climate offices and are therefore intimately familiar with their programs. The Working Group is the direct channel by which information flows between NCPO and agencies, and issues to be discussed by CPPB are raised first with the Working Group. Program priorities, for example, are formulated with the help of suggestions from the Working Group and then brought before CPPB.

The Interagency Climate Working Group is also a coordinating body, although most coordination is effected directly within program activities among program managers. The Working Group does help to identify areas where better communication or collaboration is needed.

C. Leadership for Principal Thrusts

The Principal Thrusts of this and subsequent Plans are the highest priorities of the National Climate Program. They cross program component lines and agency structures and require continuing management attention. No Principal Thrust has been or will be recommended unless an agency is identified which accepts leadership responsibility for it.

Leadership responsibilities for the six current Principal Thrusts are as follows:

Principal Thrust	Lead Agency
Generation and Dissemination of Climate Information	National Oceanic and Atmospheric Administration
Climate Prediction	National Oceanic and Atmospheric Administration
Carbon Dioxide, Environment, and Society	Department of Energy
Climate and World Food Production	United States Department of Agriculture
Solar and Earth Radiation	National Aeronautics and Space Administration
Ocean Heat Transport and Storage	National Science Foundation

The lead agencies are to coordinate detailed program planning and implementation, and to provide periodic assessments of progress in reaching the established goals. The descriptions, missions, and tasks of the Principal Thrusts are all based on material and drafts contributed by the lead agencies.

Special management structures may be needed for individual Principal Thrusts, depending on the complexity of the program and the preferences of the lead agency. For the CO_2 Thrust, for example, DOE requested and NCPO established a formal interagency committee to support their management functions. In addition, each of the lead agencies is expected to establish procedures to assure input to the planning from external constituencies.

NCPO will look to the lead agencies for revisions to plans, budget requirements, statements of agency responsibilities, and analyses of progress. NCPO will then incorporate such recommendations and analyses into its recommendations and reports to OMB, the President, and the Congress.

D. Budget Process and the Special Climate Budgetary Analysis

Specific budget requests for the National Climate Program stem from the 5-year Plan. The process uses the Plan for guidance, looks to zero-based budgeting procedures to establish priorities within agencies, and finally provides OMB with NCPO analyses and recommendations with regard to integrity of the total National Program.

Early in the budget cycle, NCPO will remind agencies of the implications of the current Plan for their budgets, calling attention both to needs for continuing activities and options for program development. Each agency will develop appropriate program descriptions and proposals. Obviously, in each agency, proposals for new climate efforts will compete with ongoing climate activities, and both will compete with nonclimate activities. In the course of this internal agency process, informal communication will continue between agency climate offices (or Working Group members) and NCPO. Throughout this period (usually February to July) of agency budget and program development, NCPO will be working closely with the agencies in sharing of information, monitoring the multiagency pattern for the Program, and reviewing new proposals.

OMB Circular A-11 requires that agencies submit, as a part of their budget submission to OMB, a listing of their requests for the Climate Program. This is to comply with Section 5(g)(1) of the National Climate Program Act. The listing becomes the basic information which allows the requests to be reviewed by OMB "as an integrated, coherent, multiagency request" (Sec. 5(g)(1)). OMB asks NCPO for a Special Analysis of the agencies' requests. NCPO compares the total request and its components with the requirements of the Plan, and expresses its judgment on the extent to which the proposed programs and funding

will permit Climate Program objectives and milestones to be met. The NCPO analysis includes an ordered ranking of climate budget priorities from the agency requests. This Special Analysis is presented to OMB and also is distributed back to the agencies participating in the Program.

The Special Analysis is the mechanism for bringing the highest priority needs of the Climate Program to the attention of those making the final budget decisions, and to inform them of the extent to which climate goals and priorities would be met through agency requests. Once the budget decisions are made, it may be necessary to modify the timetables or specific expectations outlined in the Plan. Such modifications to the Plan will be included in the Annual Report along with a summary of the multiagency budget request for the Climate Program.

E. Evaluation

Evaluation of the Program and its implementation obviously will be undertaken by the users and potential users of climate information, by the Congress, and by various advisory groups. However, to meet its planning and coordination responsibilities, NCPO will establish an in-depth internal review process.

The basic scientific and technical evaluation of Climate Program activities will be carried out through a peer review process. Each year NCPO will select, for in-depth review, a set of subactivities. (A 3-year review cycle for the entire Program is now contemplated.) Experts will be selected and asked to review current and recent efforts. Each evaluation will be made over a 6-month to 1-year period and will lead to a written report to NCPO. These reports will be used by NCPO in preparing the Annual Report and modifying the Plan, and will be provided directly to the agencies managing the specific projects and activities.

The NCPO will also sponsor periodic meetings of reviewers to help assure consistency among reviews, and also to report to the scientific and technical community and to the public on the state of climate science and applications.

In addition to this peer review process, NCPO will request annual progress reports from those agencies having lead responsibility for Principal Thrusts. These reports are to describe achievements and relate them to previously stated expectations. NCPO will prepare similar reports on each Area of Program Concern. These will form a set of documents for review by the CPPB and the National Climate Program Advisory Committee.

F. Advisory Groups and External Contacts

1. National Climate Program Advisory Committee

The National Climate Program Advisory Committee has been established as required by the National Climate Program Act. The charter and initial membership of this Committee are included in Appendix IV.

The Committee is established to "advise the Secretary and the Congress on the conduct of the Program." The Committee will provide reports and recommendations for the Secretary and the Congress, and more frequent inputs and advice to the Administrator of NOAA, the Director of NCPO (who serves the Committee as Executive Secretary), and the climate program officials of the various agencies. By the charter for the Committee, the Administrator of NOAA assumes formal responsibility for receiving reports of the Committee and for forwarding them to the proper recipient.

The Committee will determine its own emphases and mode of operation and will be the principal source of review and advice on the overall operations, and on management, program balance, international activities, relations with other national priorities, and general technical content of the Program.

The Committee's membership is diverse and contains expertise from many areas. Nevertheless, it may wish to retain experts and consultants to support particular analyses. If needed, NCPO will provide such support as resources permit. The Committee is also encouraged to recognize the competence and experience of other bodies (e.g., Climate Research Board of the National Research Council, National Academy of Sciences) and turn to them for assistance when thought necessary or helpful.

2. National Research Council, National Academy of Sciences (NRC/NAS)

Several boards and committees of the NRC/NAS have taken an active interest in climate and its effects, and are providing valuable advice to the Government. The one that has contributed most actively and been most intimately associated with the development of the National Climate Program is the Climate Research Board (CRB). Since its formation in 1977, the CRB has acted as a focus within the NRC for a broad range of studies of climate issues and has been extremely helpful in the initial formulation of the National Climate Program and this Plan. There will be continued reliance on CRB for technical and programmatic advice and counsel.

There have been two active panels of CRB: a Panel on the Effective Use of Climate Information in Decision-Making and a Committee on International Climate Programs.

The decision-making panel has examined a small number of examples of governmental use of climate information in making repetitive decisions. The purpose was to learn more about what kinds of information are needed, how to make the information more useful, and how to structure the decision framework so that climate information will be used more effectively. The panel has prepared a report that the Academy is reviewing.

The international committee has been providing continuing advice to the Government with regard to the creation, structure, and activities of the World Climate Program.

There is significant involvement of nongovernmental international organizations in the World Climate Program. The National Academy of Sciences is the formal channel through which the United States participates in such nongovernmental international scientific bodies. Recently, the CRB dissolved the internal panel and will act as a committeee-of-the-whole on international programs.

Activities of the CRB are supported through multiagency contributions channeled through NCPO.

3. Other contacts

The importance of broad user involvement in the planning for the National Climate Program has been emphasized repeatedly in Congressional reports and in other recommendations. To be in frequent contact with its user groups, the Office will rely very heavily on operating climate entities, such as the National Climatic Center, the Climate Analysis Center, and the DOE's Carbon Dioxide and Climate Division. The National Climate Program Advisory Committee and the Climate Research Board, in view of their very broad memberships, will also attract useful contributions from user committees. NCPO will maintain active contact with groups such as the American Association of State Climatologists; establish formal contacts with State governments; and continue to meet with and hear from such groups as Regional River Basin Commissions, the Agricultural Research Institute, and the Chemical Manufacturers Association.

CHAPTER IX

RESOURCES AND FUTURE PLANS

A. Funding for the National Climate Program

Current and planned funding for the activities of the National Climate Program for FY 1979-84 are presented in tables 11 and 12. Table 11 shows the funds by agency, and table 12 shows how the funds are distributed among major Program components. The requests for FY 1981 and the projections for FY 1982-84 are from the President's budget.

Table 11.—Agency climate budget summary (Budget Authority by Fiscal Year, $M)

	Fiscal Year					
Agency	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**
Agriculture	15.0	17.1	16.8	16.8	16.8	16.8
Commerce	18.2	21.6	24.5	24.5	24.5	24.5
Defense	8.0	8.7	9.3	9.7	10.6	11.3
Energy	4.5	7.7	13.5	14.4	14.5	14.5
Interior	4.2	5.4	5.7	4.7	3.6	2.4
NASA	12.9	27.7	29.4	34.0	21.7	15.6
NSF	25.3	26.8	27.5	29.0	30.7	31.6
Total	88.1	115.0	126.7	133.1	122.4	116.7

The FY 1981 budget request for climate is $126.7 million —10.2 percent greater than FY 1980 and an increase of more than 40 percent over FY 1979. The largest single factor in the increase over FY 1979 is the cost associated with NASA's Earth Radiation Budget Experiment. Budget projections for FY 1983-84 show a significant decrease from FY 1982, because most of the costs associated with that experimental satellite program will have been met.

Efforts in both Impact Assessment and in Climate System Research are receiving increased support in FY 1980 and 1981 *via* activities now designated as Principal Thrusts. The Department of Agriculture has increased resources to assess climate impact on world food production, the Department of Commerce (NOAA) and the National Science Foundation will initiate joint activities in 1981 on ocean heat transport and storage, and the Department of Energy is increasing significantly research on CO_2 and its effects. Other increases in both Impact Assessment and Climate System Research are being directed to various Areas of Program Concern.

There are no significant increases in support for Data, Information, and Services other than that related to solar and Earth radiation studies. However, plans related to accelerated future efforts in Providing Climate Products (Chapter III) are proceeding, and options to provide greater support in these areas will be given careful consideration in the FY 1982 budget.

B. Budget Options and Recommendations

The budget projections presented in tables 11 and 12 are estimates of future costs associated with now-approved programs. These programs are carefully reevaluated each year, and the opportunity exists to consider new or alternate activities.

Table 12.—Budget authority for National Climate Program ($ Million)

	Fiscal Year					
	1979 (E[1])	**1980 (A[2])**	**1981 (R[3])**	**1982 (P[4])**	**1983 (P[4])**	**1984 (P[4])**
Impact Assessment	18.5	22.5	25.8	26.1	26.6	26.7
Climate System Research	25.6	30.3	36.2	40.0	40.2	41.9
Data, Information, and Services	43.6	61.6	64.1	66.3	54.9	47.5
Observations	(24.3)	(39.4)	(41.4)	(43.4)	(32.0)	(25.2)
Data Management	(13.2)	(15.5)	(15.9)	(16.1)	(16.1)	(15.5)
Analysis and Projection	(3.3)	(3.9)	(3.8)	(3.8)	(3.8)	(3.8)
Information Services	(2.8)	(2.8)	(3.0)	(3.0)	(3.0)	(3.0)
Program Management	0.4	0.6	0.6	0.6	0.6	0.6
Total	88.1	115.0	126.7	133.0	122.3	116.7

[1]E = estimated
[2]A = appropriated
[3]R = requested
[4]P = planned

Table 13.—Priorities and possible costs of options for future program development

	NCPO Priority Category	Annual costs of options if implemented fully* (Millions of dollars)
PRINCIPAL THRUST		
Providing Climate Products:		
Generation and Dissemination of Climate Information	1	2.5 to 5.0
Climate Prediction	1	1.5 to 3.0
Responding to Impacts and Policy Implications of Climate:		
Carbon Dioxide, Environment, and Society	2	5.0 to 10.0
Climate and World Food Production	3	1.0 to 1.5
Understanding Climate:		
Solar and Earth Radiation	3	4.0 to 12.0
Ocean Heat Transport and Storage	3	4.0 to 5.0
AREA OF PROGRAM CONCERN		
Providing Climate Products:		
Surface Climate Data Networks	4	0.2
Responding to Impacts and Policy Implications of Climate:		
Energy Production, Distribution, and Demand	4	0.5 to 1.5
Regional Climate Effects of Humans	5	2.0 to 3.0
Understanding Climate:		
Air-Sea Interaction	5	2.0 to 4.0
Polar Ice and Snow	5	3.0 to 5.0
Stratospheric Processes	4	1.0 to 2.0

*Partial implementation would reduce costs.

This Plan presents several program options that can be considered for Fiscal Years 1982-84. Table 13 summarizes the costs that would be incurred if those options were implemented fully. All of these options are associated with activities of priority concern to the National Climate Program and are discussed in detail in Part II of the Plan.

Of the options, the ones deserving the strongest support are for Principal Thrusts associated with Providing Climate Products. The resources needed for Generation and Dissemination of Climate Information and for Climate Prediction are modest in terms of the Program's total resources, but promise very substantial benefits from that investment. These options would tend to establish a better balance in the Program between acquiring new knowledge and applying that knowledge.

Next in importance is the option associated with the CO_2 issue. About half of the cost of this budget option is to strengthen research on biogeochemical cycles. Other costs are to initiate a vigorous effort in assessing the environmental, economic, and social implications of increased CO_2. Planning in 1980 will lead to better definition of specific assessment activities and provide sounder justifications for specific outyear amounts. Further increases may prove warranted as the scientific and societal issues are clarified. Planning is proceeding to identify the tasks that need to be addressed and the talent and institutions capable of dealing with them.

Table 13 shows additional rankings of importance among the program options. These rankings must be viewed from the perspective that all options associated with Program activities are of high priority.

C. Revising the Plan

The National Climate Program Act requires that the Plan "be revised and extended biennially." The Plan may be changed more frequently with such changes included in the annual report to the Congress (Sec. 7). The preparation of these changes, revisions, and extensions is a continuing activity led by NCPO.

In certain respects this continuing planning effort will differ significantly from that which led to the present Plan:

- The Climate Program Advisory Committee will have a significant role in determining the content and priorities of future versions of the Plan. (The Committee was appointed too late to influence the present plan.)
- The agencies with lead responsibilities for Principal Thrusts will contribute more fully to the planning process. Each will be involved with particular user groups and will be channeling the inputs from these constituencies directly into their planning.
- Results of ongoing planning studies and evaluations will be available to influence future planning activities. Revised Plans will tend to recommend particular directions for the Program because of the findings of completed studies rather than point to the need for specific studies.

The cycle for revising the Plan and the Federal budget cycle are closely coupled. Figure 9 shows a flow chart.

Agencies' budget requests will be influenced by this Plan and its revisions, although preparation of FY 1982 budget requests has already begun. The first stages of preparation of the "revised and extended" Plan will begin early in 1981, about the time of Congressional receipt of the Annual Report for Fiscal Year 1980. The most critical period for program decisions will be the first several months. By

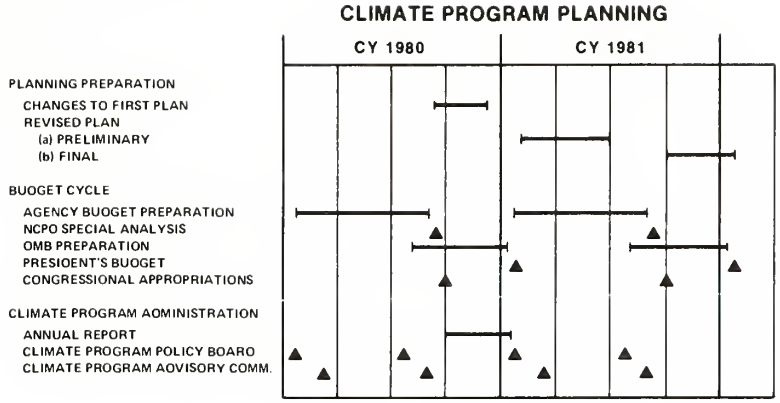

Figure 9.—National Climate Program planning schedule.

early summer a decision must be made, requiring Climate Program Policy Board approval, on basic priorities. Specific recommendations will be sought from the Advisory Committee, from other outside groups, and from Federal agencies.

Such priority decisions have to be made by July 1981 in order to influence the deliberations of the agencies on their FY 1983 budget requests, and to publicize and obtain feedback from the public on the priority decisions. Final plan preparation will begin in October.

The second 5-year Plan for the National Climate Program will be promulgated in February 1982, in time for the Congress to consider it in connection with the Fiscal Year 1983 budget.

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U.S. Committee for the Global Atmospheric Research Program (1978): Elements of the Research Strategy for the United States Climate Program, Report of the Climate Dynamics Panel; National Academy of Sciences, Washington, D.C.

APPENDIX I

A CHRONOLOGICAL SEQUENCE OF SELECTED REPORTS THAT HAVE STIMULATED PRESENT INTEREST IN CLIMATE AND HELPED TO EVOLVE PRESENT PROGRAM DIRECTIONS

1971

Wilson, C.L. (Chairman): **Inadvertent Climate Modification, Report of the Study of Man's Impact on Climate (SMIC).** W. H. Matthews, W. W. Kellogg, and G. D. Robinson, eds.; MIT Press, Cambridge, Mass.

A distinguished international group of experts expressed the view that man may be altering the climate inadvertently and recommended systematic studies of past climates and extensive research on the processes that influence climate.

1973

National Oceanic and Atmospheric Administration, Office for Environmental Monitoring and Prediction: **The Influence of Weather and Climate on United States Grain Yields; Bumper Crops or Droughts.** A Report to the Administrator, NOAA; Washington, D.C.

This technical study demonstrated the importance of climate to grain production and suggested that the preceding 15-year span of favorable conditions was unlikely to persist.

1974

Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences (ICAS): **Report of the *Ad Hoc* Panel on the Present Interglacial;** Washington, D.C.

A small group of government experts discounted the suggested imminence of a new glacial climate, but recommended greatly augmented research on climate. ICAS established a group to plan a National Climate Program.

World Meteorological Organization, International Council of Scientific Unions, Joint Organizing Committee: **The Physical Basis of Climate and Climate Modeling.** GARP Publications Series, No. 16, World Meteorological Organization, Geneva (published in 1975).

An international body of scientists, meeting in Stockholm at an atmospheric research study conference, and citing the SMIC report and other studies, unanimously recommended a comprehensive research program on the climate of the Earth.

U.N. World Food Conference, Rome (Nov. 5-16, 1974).

An international body of government and technical experts urged early establishment of a Global Information and Early Warning System on Food and Agriculture, and established the World Food Council to follow up on Conference recommendations.

U.S. Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change: **A United States Climate Program**, Washington, D.C.

Government analysts recommended that a U.S. climate program be conducted to (a) establish a climate impact warning system, (b) improve monthly and seasonal predictions, (c) develop mathematical computer models for predicting climate and man's impact on climate and (d) develop a global climate monitoring system.

National Advisory Committee on Oceans and Atmosphere: Report to the President and the Congress, Third Annual Report, NACOA, Washington, D.C.

Academic and industrial advisors issued a series of recommendations on climate research and the use of climate information in agricultural planning and energy generating plant siting.

U.S. Department of Transportation, Climate Impact Assessment Program (a series of monographs, interim and final reports), Washington, D.C.

An extensive technical evaluation of the potential impact of inadvertent modification of the stratosphere revealed the vulnerability of the upper atmosphere to change due to human activities.

1975

National Academy of Sciences: **Understanding Climatic Change, A Program for Action,** NAS, Washington, D.C.

A scientific panel of the U.S. Committee for the Global Atmospheric Research Program offered some assurance that success in understanding "the basic physical forces affecting climate" was possible; an outline for a comprehensive national climate research program was recommended.

National Academy of Sciences, Climate Impact Committee: **Environmental Impact of Stratospheric Flight, NAS, Washington, D.C.**

A technical report was issued that expressed concern that a large fleet of high flying aircraft (a proposed option for technology development) could lead to a diminution of stratospheric ozone, with adverse health (and climate) effects.

U.S. Congress: H.R. 10013

A Bill was introduced to authorize and direct the establishment of a coordinated national program relating to climate. The Bill followed the lines recommended in the earlier Domestic Council report.

1976

National Academy of Sciences: **Climate and Food, Climatic Fluctuation and U.S. Agricultural Production,** NAS, Washington, D.C.

A report of the Committee on Climate and Weather Fluctuations and Agricultural Production recommended research to address needs for accurate seasonal, annual and long-range climate forecasts and to define and understand the impact of climate on agriculture.

Federal Council for Science and Technology, Interagency Task Force on Inadvertent Modification of the Stratosphere: **A Proposed Federal Research Program to Determine the Biological and Climatic Effects of Stratospheric Ozone Reductions,** Washington, D.C.

Government experts recommended a program to examine the climate of the stratosphere, its vulnerability to change, and the impact of such changes.

World Meteorological Organization, Geneva

An international body of experts issued a statement calling for additional monitoring and research on climate and factors that may cause climate variations.

1977

National Academy of Sciences: **Energy and Climate,** NAS, Washington, D.C.

A report of the Panel on Energy and Climate called attention to potential climate changes that increasing atmospheric carbon dioxide may portend.

Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences: **A United States Climate Program Plan,** Washington, D.C.

An interagency group planned and proposed a national climate program "to help the Nation respond more effectively to climate-induced problems." The plan identified research and service needs in five categories: impact assessments, diagnosis and projection of climate variability, research, observations and data management.

1978

U.S. Congress: Conference Report to accompany H.R. 6669, **The National Climate Program Act,** Washington, D.C.

The House and Senate agreed on the format for a National Climate Program. The Program was enacted a month after the publication of the Conference Report (PL 95-367).

National Academy of Sciences: **Elements of the Research Strategy for the United States Climate Program,** NAS, Washington, D.C.

The Climate Dynamics Panel to the U.S. Committee for the GARP reviewed climate research needs and recommended a strategy for attaining a better understanding of climate and climate processes and suggested the first step should address the annual cycle of climate.

1979

National Academy of Sciences: **Toward a U.S. Climate Program Plan,** Report of the Workshop to Review the U.S. Climate Program Plans, July 12-19, 1978: NAS, Washington, D.C.

The Climate Research Board reviewed individual Federal agency climate plans and examined the current state of planning for the National Program, and offered technical guidance on developing the integrated program of climate research and applications.

World Climate Conference: A Conference of Experts on Climate and Mankind, Geneva (Feb. 12-23, 1979).

An international group of experts was convened to assess the state of man's knowledge of climate and to consider the effects of climate variability and change on human society. The Conference reviewed an International Plan of Action for the study of impact of climate upon society for transmittal to the Congress of the World Meteorological Organization.

National Academy of Sciences: **Carbon Dioxide and Climate: A Scientific Assessment,** NAS, Washington, D.C.

A study group of the Climate Research Board reviewed the current understanding of climate processes and concluded that if carbon dioxide continues to increase in the atmosphere, significant climate changes are likely to result.

National Academy of Sciences: **A Strategy for the National Climate Program,** Report of a Workshop to Review the Preliminary National Climate Program Plan, July 16-21, 1979, NAS, Washington, D.C.

The Climate Research Board reviewed current planning for the National Climate Program and offered guidance for improving the strategy contained in the Preliminary Plan.

National Academy of Sciences: **The Continuing Quest—Large-Scale Ocean Science for the Future,** NAS, Washington, D.C.

Ocean processes contributing to climate and other environmental changes are reviewed.

National Oceanic and Atmospheric Administration, Environmental Research Laboratories: **An Ocean Climate Research Plan,** NOAA, Boulder, Colorado.

A series of projects needed to clarify the role of the ocean in the climate system is outlined.

Public Law 95-367
95th Congress

An Act

To establish a comprehensive and coordinated national climate policy and program, and for other purposes.

Sept. 17, 1978
[H.R. 6669]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Climate Program Act".

National Climate Program Act.
15 USC 2901 note.

SEC. 2. FINDINGS.

15 USC 2901.

The Congress finds and declares the following:

(1) Weather and climate change affect food production, energy use, land use, water resources and other factors vital to national security and human welfare.

(2) An ability to anticipate natural and man-induced changes in climate would contribute to the soundness of policy decisions in the public and private sectors.

(3) Significant improvements in the ability to forecast climate on an intermediate and long-term basis are possible.

(4) Information regarding climate is not being fully disseminated or used, and Federal efforts have given insufficent attention to assessing and applying this information.

(5) Climate fluctuation and change occur on a global basis, and deficiencies exist in the system for monitoring global climate changes. International cooperation for the purpose of sharing the benefits and costs of a global effort to understand climate is essential.

(6) The United States lacks a well-defined and coordinated program in climate-related research, monitoring, assessment of effects, and information utilization.

SEC. 3. PURPOSE.

15 USC 2902.

It is the purpose of the Congress in this Act to establish a national climate program that will assist the Nation and the world to understand and respond to natural and man-induced climate processes and their implications.

SEC. 4. DEFINITIONS.

15 USC 2903.

As used in this Act, unless the context otherwise requires:

(1) The term "Office" means the National Climate Program Office.

(2) The term "Program" means the National Climate Program.

(3) The term "Secretary" means the Secretary of Commerce.

SEC. 5. NATIONAL CLIMATE PROGRAM.

15 USC 2904.

(a) ESTABLISHMENT.—The President shall establish a National Climate Program in accordance with the provisions, findings and purposes of this Act.

(b) DUTIES.—The President shall—

(1) promulgate the 5-year plans described in subsection (d)(9);

(2) define the roles in the Program of Federal officers, departments, and agencies, including the Departments of Agriculture, Commerce, Defense, Energy, Interior, State, and Transportation; the Environmental Protection Agency; the National Aeronautics

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and Space Administration; the Council on Environmental Quality; the National Science Foundation; and the Office of Science and Technology Policy; and

(3) provide for Program coordination.

Establishment.

(c) NATIONAL CLIMATE PROGRAM OFFICE.—The Secretary shall establish within the Department of Commerce a National Climate Program Office not later than 30 days after the date of the enactment of this Act. The Office shall be the lead entity responsible for administering the Program. Each Federal officer, employee, department and agency involved in the Program shall cooperate with the Secretary in carrying out the provisions of this Act.

Administration.

(d) PROGRAM ELEMENTS.—The Program shall include, but not be limited to, the following elements:

(1) assessments of the effect of climate on the natural environment, agricultural production, energy supply and demand, land and water resources, transportation, human health and national security. Such assessments shall be conducted to the maximum extent possible by those Federal agencies having national programs in food, fiber, raw materials, energy, transportation, land and water management, and other such responsibilities, in accordance with existing laws and regulations. Where appropriate such assessments may include recommendations for action;

(2) basic and applied research to improve the understanding of climate processes, natural and man induced, and the social, economic, and political implications of climate change;

(3) methods for improving climate forecasts on a monthly, seasonal, yearly, and longer basis;

(4) global data collection, and monitoring and analysis activities to provide reliable, useful and readily available information on a continuing basis;

(5) systems for the management and active dissemination of climatological data, information and assessments, including mechanisms for consultation with current and potential users;

(6) measures for increasing international cooperation in climate research, monitoring, analysis and data dissemination;

(7) mechanisms for intergovernmental climate-related studies and services including participation by universities, the private sector and others concerned with applied research and advisory services;

(8) experimental climate forecast centers, which shall (A) be responsible for making and routinely updating experimental climate forecasts of a monthly, seasonal, annual, and longer nature, based on a variety of experimental techniques; (B) establish procedures to have forecasts reviewed and their accuracy evaluated; and (C) protect against premature reliance on such experimental forecasts; and

Five-year plan, submittal to Congress.

(9) a preliminary 5-year plan, to be submitted to the Congress for review and comment, not later than 180 days after the enactment of this Act, and a final 5-year plan to be submitted to the Congress not later than 1 year after the enactment of this Act, that shall be revised and extended biennially. Each plan shall establish the goals and priorities for the Program, including the intergovernmental program under section 6, over the subsequent 5-year period, and shall contain details regarding (A) the role of Federal agencies in the programs, (B) Federal funding required to enable the Program to achieve such goals, and (C) Program accomplish-

ments that must be achieved to ensure that Program goals are met within the time frame established by the plan.

(e) ADVISORY COMMITTEE AND INTERAGENCY GROUPS.—(1) The Secretary shall establish and maintain an advisory committee of users and producers of climate data, information and services to advise the Secretary and the Congress on the conduct of the Program. Members of such committee shall not be employed by the Federal Government and may receive compensation at the daily rate for GS-16 of the General Schedule for each day engaged in the actual performance of their duties for the committee and while so serving away from their homes or regular place of business may be allowed travel expenses, including per diem in lieu of subsistence. Establishment. 5 USC 5332 note.

(2) The Secretary shall establish and maintain such interagency groups as are necessary and appropriate to assist in carrying out responsibilities under this Act.

(f) COOPERATION.—(1) The Program shall be conducted so as to encourage cooperation with, and participation in the Program by, other organizations or agencies involved in related activities. For this purpose the Secretary shall cooperate and participate with other Federal agencies, and foreign, international, and domestic organizations and agencies involved in international or domestic climate-related programs.

(2) The Secretary and the Secretary of State shall cooperate in (A) providing representation at climate-related international meetings and conferences in which the United States participates, and (B) coordinating the activities of the Program with the climate programs of other nations and international agencies and organizations, including the World Meteorological Organization, the International Council of Scientific Unions, the United Nations Environmental Program, the United Nations Educational, Scientific, and Cultural Organization, the World Health Organization, and Food and Agriculture Organization.

(g) BUDGETING.—(1) Each Federal agency and department participating in the Program, shall prepare and submit to the Office of Management and Budget, on or before the date of submission of departmental requests for appropriations to the Office of Management and Budget, an annual request for appropriations for the Program for the subsequent fiscal year. The Office of Management and Budget shall review the request for appropriations as an integrated, coherent, multiagency request. Annual appropriation request to OMB.

(2) Section 304 of the Act of October 18, 1962 (31 U.S.C. 25) (relating to preparation of horizontal budgets for meteorology), is amended— Horizontal budgets.

(A) by inserting "and of the National Climate Program established under the National Climate Program Act" after "meteorology", and

(B) by striking out "aspects of the program" and inserting in lieu thereof "aspects of the programs".

The amendments made by the preceding sentence shall apply with respect to budgets submitted for fiscal years beginning 6 months or more after the date of the enactment of this Act. Effective date. 31 USC 25 note.

SEC. 6. INTERGOVERNMENTAL CLIMATE PROGRAMS. 15 USC 2905.

(a) ESTABLISHMENT.—The Secretary shall establish a program for Federal and State cooperative activities in climate studies and advisory services. The Secretary is authorized to make annual grants to any State or group of States, such grants to be made available to public or private educational institutions, to State agencies and to other persons or institutions qualified to conduct climate-related studies or provide Federal and State cooperative activities. Grants.

Limitation.

Restriction.

climate-related services. Such grants may be made for not more than 50 percent of the costs, in any one year, of the research conducted or services provided under the grant. Federal funds received from other sources shall not be used to pay the remaining share of the cost of such research or services. The Secretary shall work with other appropriate mission agencies in conducting this program.

(b) DETAIL OF THE INTERGOVERNMENTAL PROGRAM.—The intergovernmental program shall provide, among others, the following State and regional services and functions:

(1) studies relating to and analyses of climatic effects on agricultural production, water resources, energy needs, and other critical sectors of the economy;

(2) atmospheric data collection and monitoring on a statewide and regional basis;

(3) advice to regional, State, and local government agencies regarding climate-related issues;

(4) information to users within the State regarding climate and climatic effects; and

(5) information to the Secretary regarding the needs of persons within the State for climate-related services, information and data.

(c) INTERGOVERNMENTAL PROGRAM REQUIREMENTS.—Prior to making a grant to any State or group of States under this section, the Secretary shall find that—

(1) the State, or each of the States in a group, has adopted a State climate program in accordance with the provisions of this Act and rules and regulations promulgated by the Secretary; and

(2) the State, or each of the States in a group has—

(A) integrated its climate program with the Program; and

(B) established an effective mechanism for consultation and coordination with Federal and local government officials and users within the State.

The Secretary shall insure that grants made to a State or group of States under this section are made on an equitable basis.

15 USC 2906.

Report to President and congressional committees.

SEC. 7. ANNUAL REPORT.

The Secretary shall prepare and submit to the President and the authorizing committees of the Congress, not later than January 30 of each year, a report on the activities conducted pursuant to this Act during the preceding fiscal year, including—

(a) a summary of the achievements of the Program during the previous fiscal year;

(b) an analysis of the progress made toward achieving the goals and objectives of the Program;

(c) a copy of the 5-year plan and any changes made in such plan;

(d) a summary of the multiagency budget request for the Program of subsection 5(g); and

(e) any recommendations for additional legislation which may be required to assist in achieving the purposes of the Act.

15 USC 2907.

SEC. 8. CONTRACT AND GRANT AUTHORITY; RECORDS AND AUDITS.

(a) Functions vested in any Federal officer or agency by this Act or under the Program may be exercised through the facilities and personnel of the agency involved or, to the extent provided or approved in advance in appropriation Acts, by other persons or entities under contracts or grant arrangements entered into by such officer or agency.

(b)(1) Each person or entity to which Federal funds are made available under a contract or grant arrangement as authorized by this Act shall keep such records as the Director of the Office shall prescribe, including records which fully disclose the amount and disposition by such person or entity of such funds, the total cost of the activities for which such funds were so made available, the amount of that portion of such cost supplied from other sources, and such other records as will facilitate an effective audit. Record keeping.

(2) The Director of the Office and the Comptroller General of the United States, or any of their duly authorized representatives, shall, until the expiration of 3 years after the completion of the activities (referred to in paragraph (1)) of any person or entity pursuant to any contract or grant arrangement referred to in subsection (a), have access for the purpose of audit and examination to any books, documents, papers, and records of such person or entity which, in the judgment of the Director or the Comptroller General, may be related or pertinent to such contract or grant arrangement. Accessibility to records.

SEC. 9. AUTHORIZATION FOR APPROPRIATIONS. 15 USC 2908.

(a) GENERAL AUTHORIZATION OF APPROPRIATION.—In addition to any other funds otherwise authorized to be appropriated for the purpose of conducting climate-related programs, there are authorized to be appropriated to the Secretary, for the purpose of carrying out the provisions of this Act, not to exceed $50,000,000 for the fiscal year ending September 30, 1979, and not to exceed $65,000,000 for the fiscal year ending September 30, 1980.

(b) AUTHORIZATION OF APPROPRIATION FOR GRANTS.—There are authorized to be appropriated to the Secretary sums not to exceed $10,000,000 for the fiscal year ending September 30, 1979, and not to exceed $10,000,000 for the fiscal year ending September 30, 1980, as may be necessary for grants under section 6 of this Act, to remain available until expended.

Approved September 17, 1978.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 95-266 (Comm. on Science and Technology) and No. 95-1489 (Comm. of Conference).
SENATE REPORT No. 95-740 (Comm. on Commerce, Science, and Transportation).
CONGRESSIONAL RECORD:
Vol. 123 (1977): Sept. 9, considered and passed House.
Vol. 124 (1978): Apr. 24, considered and passed Senate, amended.
Aug. 17, Senate agreed to conference report.
Sept. 6, House agreed to conference report.

APPENDIX III

STATE GOVERNORS' REPRESENTATIVES AND STATE CLIMATOLOGISTS JULY, 1980

State	Official Representative to NCPO	State Climatologist
Alabama	Charles Busch	Eugene A. Carter
Alaska	Ernst W. Mueller	James Wise
Arizona	Louis J. Battan	Anthony J. Brazel
Arkansas	John G. Hehr	———
California	Robert W. Miller	James Goodridge
Colorado	Thomas McKee	Thomas McKee
Connecticut	Hugo F. Thomas	David R. Miller
Delaware	John R. Mather	John R. Mather
Florida	John Bottcher	Clark I. Cross
Georgia	———	Gayther L. Plummer
Hawaii	Susumu Ono	Saul Price
Idaho	Myron Molnau	Myron Molnau
Illinois	Stanley A. Changnon	Stanley A. Changnon
Indiana	Lawrence A. Schaal	Lawrence A. Schaal
Iowa	Paul Waite	Paul Waite
Kansas	Byron Wood	L. Dean Bark
Kentucky	Glen Connor	Glen Connor
Louisiana	Robert A. Muller	Robert A. Muller
Maine	David Tudor	———
Maryland	Orman E. Street	W. J. Moyer
Massachusetts	Charles F. Kennedy	R. E. Lautzenheiser
Michigan	Fred V. Nurnberger	Fred V. Nurnberger
Minnesota	Earl Kuehnast	Earl Kuehnast
Mississippi	Charles Chisolm	———
Missouri	Wayne L. Decker	Wayne L. Decker
Montana	Joseph M. Caprio	Joseph M. Caprio
Nebraska	Martin Massengale	Norman J. Rosenberg
Nevada	Richard O. Gifford	Richard O. Gifford
New Hampshire	Gerard Pregent	Gerard Pregent
New Jersey	A. Vaughn Havens	A. Vaughn Havens
New Mexico	William P. Stephens	William P. Stephens
New York	James E. Jiusto	Bernard E. Dethier
North Carolina	Peter Robinson	Peter Robinson
North Dakota	Lynn Rose	John W. Enz
Ohio	John M. Stackhouse	John N. Rayner
Oklahoma	Amos Eddy	Amos Eddy
Oregon	Robert Montgomery	W. Lawrence Gates

State	Official Representative to NCPO	State Climatologist
Pennsylvania	———	———
Rhode Island	———	———
South Carolina	Eugene A. Laurent	Richard G. Silvernail
South Dakota	Warren R. Neufeld	William Lytle
Tennessee	James Reed	———
Texas	John F. Griffiths	John F. Griffiths
Utah	E. Arlo Richardson	E. Arlo Richardson
Vermont	Reginald A. La Rosa	———
Virginia	Bruce Hayden	Bruce Hayden
Washington	Howard J. Critchfield	Howard J. Critchfield
West Virginia	John D. Anderson	———
Wisconsin	Charles Engman	Val L. Mitchell
Wyoming	———	———

APPENDIX IV

U.S. DEPARTMENT OF COMMERCE CHARTER OF THE NATIONAL CLIMATE PROGRAM ADVISORY COMMITTEE

A. Establishment

The National Climate Program Advisory Committee (the "Committee" hereinafter) is established by the Secretary of Commerce (the "Secretary") under the authority of and as directed by Section 5(e)(1) of the National Climate Program Act of 1978 (the "Act"), Public Law 95-367. In accordance with the provisions of the Federal Advisory Committee Act, the Committee is hereby chartered.

B. Explanation of Terms

The terms used in his Charter shall have the meanings that are prescribed in the Act.

C. Objectives and Duties

1. The Committee shall review all aspects of the Nation's Climate activities, and based on its findings, shall advise and report to the Secretary and the Congress through the Administrator of the National Oceanic and Atmospheric Administration (the "Administrator") on the conduct and priorities of the program, the scientific rigor of the research aspects, and the effectiveness and appropriateness of the service aspects.

2. The Committee shall also make recommendations with respect to actions the United States, and the U.S. National Climate Program Office should take to strengthen international efforts to measure, understand and respond to climate and climate changes.

3. The Committee functions solely as an advisory body, and will comply fully with the provisions of the Federal Advisory Committee Act.

D. Members and Chairperson

1. The Committee shall consist of not more than 15 members and not less than 7, appointed by the Secretary. Members of the Committee shall not be employed by the Federal Government. They will be individuals who possess familiarity or expertise in the use or production of climate data, information and services. The breadth of the membership shall reflect the scope of the program, from data acquisition to application and across many disciplines. Members shall be appointed for up to two years and will serve at the discretion of the Secretary. Appointments to fill vacancies shall be for the remainder of the unexpired term of the vacancy.

2. The Chairperson of the Committee shall be appointed by the Secretary from among the membership.

E. Administrative Provisions

1. The Director, National Climate Program Office, shall serve as Executive Secretary to the Committee.

2. Members of the Committee will normally serve without compensation. In special circumstances the Administrator may authorize compensation at the daily rate for GS-16 of the General Schedule, 5 U.S.C. 5332, for each day engaged in the actual performance of their duties for the Committee.

3. The Committee shall meet on a semi-annual basis and such other times as may be deemed necessary by the Administrator or the Chairperson.

4. Members may be allowed travel expenses, including per diem in lieu of subsistence, while serving away from their homes or regular place of business.

5. The National Oceanic and Atmospheric Administration shall provide clerical and other necessary support.

6. The annual cost of operating the Committee is estimated at $30,000, including 1/2 person-year of clerical support.

7. The Committee may establish, subject to the provisions of the Department of Commerce Committee Management Handbook (II,1.E.), and the approval of the Administrator, an Executive Committee and such subcommittees or working groups of its members as may be necessary.

8. Security clearances for Committee members shall be requested as necessary.

F. Duration

The Act directs the Secretary to establish the Committee for an indefinite duration. As provided by Section 14(b)(2) of the Federal Advisory Committee Act, a Charter shall be filed upon the expiration of of each successive two-year period following the date of enactment of the Act (September 17, 1978).

Date: 5/16/79 Signed: Assistant Secretary
for Administration

Pursuant to subsection 9(c) of the Federal Advisory Committee Act, 5 U.S.C. App. (1976), copies of this charter were filed with the following congressional committees on May 17, 1979, and a copy was furnished the Library of Congress:

——— Senate Committee on Commerce, Science and Transportation
——— House Committee on Interstate and Foreign Commerce
——— House Committee on Merchant Marine and Fisheries
——— House Committee on Science and Technology

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APPENDIX V
GLOSSARY OF ACRONYMS

AASC	American Association of State Climatologists
AgRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
AVHRR	Advanced Very High Resolution Radiometer
CAC	Climate Analysis Center/NOAA
CCCO	Committee on Climate Change in the Oceans
CPPB	Climate Program Policy Board
CRB	Climate Research Board
CRREL	Cold Regions Research and Engineering Laboratory/ U.S. Army Corps of Engineers/DOD
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EDIS	Environmental Data and Information Service/NOAA
EPA	Environmental Protection Agency
EPOCS	Equatorial Pacific Ocean Climate Studies
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ERL	Environmental Research Laboratories/NOAA
ESCS	Economics, Statistics & Cooperative Service/USDA
ETAC	Environmental Technical Applications Center/USAF
FAA	Federal Aviation Administration/DOT
FAO	Food and Agriculture Organization
FAS	Foreign Agricultural Service/USDA
FEMA	Federal Emergency Management Agency
FGGE	First GARP Global Experiment
FS	Forest Service/USDA
GARP	Global Atmospheric Research Program
GCM	General Circulation Model
GEMS	Global Environmental Monitoring System
GEOSECS	Geochemical Ocean Sections Study
GFDL	Geophysical Fluid Dynamics Laboratory/NOAA
GLAS	Goddard Laboratory for Atmospheric Sciences/NASA
GOCE	Global Ocean Circulation Experiment
GMCC	Geophysical Monitoring for Climatic Change
HAPP	High Altitude Pollution Program//FAA
HFE	Heat Flux Experiment
ICEX	Ice and Climate Experiment
ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IGOSS	Integrated Global Ocean Station System
INDEX	Indian Ocean Experiment
IOC	Intergovernmental Oceanographic Commision
ISOS	International Southern Ocean Studies
ITOS	Improved TIROS Operational Satellite
LACIE	Large Area Crop Inventory Experiment/ USDA, NOAA, and NASA
LANDSAT	Satellite Remote Sensing for Land Surface Features

MONEX	Monsoon Experiment
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research/NSF
NCC	National Climatic Center/NOAA
NCPO	National Climate Program Office/NOAA
NESS	National Environmental Satellite Service/NOAA
NIMBUS	Series of Experimental Environmental Research Satellites
NMFS	National Marine Fisheries Service/NOAA
NOAA	National Oceanic and Atmospheric Administration/DOC
NORPAX	North Pacific Experiment
NPACD	National Plan of Action to Combat Desertification
NSF	National Science Foundation
NWS	National Weather Service/NOAA
ONR	Office of Naval Research/USN
OOE	Office of Ocean Engineering/NOAA
PEQUOD	Pacific Equatorial Ocean Dynamics
POLYMODE	Polygon-Mid-Ocean Dynamics Experiment
POMS	Pilot Ocean Monitoring Study
SAGE	Stratospheric Aerosol and Gas Experiment
SCOPE	Special Committee on Problems of the Environment/ICSU
SCOR	Scientific Committee on Ocean Research/ICSU
SCS	Soil Conservation Service/USDA
SEA	Science and Education Administration/USDA
SEQUAL	Seasonal Response of Equatorial Atlantic
SMM	Solar Maximum Mission
SR	Scanning Radiometer on Mereorological Satellites
TIROS	Television Infrared Operational Satellite
TIROS N	Prototype (launched in 1979) for New Series of Operational Meteorological Satellites
UARS	Upper Atmospheric Research Satellite
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAF	United States Air Force/DOD
USDA	United States Department of Agriculture
USGS	United States Geological Survey/DOI
USN	United States Navy/DOD
WFAOSB	World Food and Agriculture Outlook and Situation Board/ USDA
WCP	World Climate Program
WMO	World Meteorological Organization
WWW	World Weather Watch
XBT	Expendable Bathythermograph

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